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## ON THE ORIGIN OF THE AMPHIBOLITES OF THE LAURENTIAN AREA OF CANADA[1]

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In a paper which appeared in the last number of this *Journal* an account was given of the development of the Grenville series in a great tract of the Laurentian Protaxis, some 4,200 square miles in extent, situated in the eastern part of the Province of Ontario, a study of which has recently been completed for the Geological Survey of Canada by Dr. A. E. Barlow and the writer.

In this tract the Grenville series is not only of great areal extent but is of enormous thickness. About one-half of this thickness consists of limestone while the remainder consists of gneisses of sedimentary origin (paragneiss), with occasional quartzites and great bodies of amphibolite. This series is invaded by enormous bathyliths of gneissic granite and while in the southeastern portion of the area toward the margin of the Protaxis, the sedimentary series is comparatively free from igneous intrusions, toward the northwest the granite in ever increasing amount arches up the sedimentary series and wells up through it, in places disintegrating it into a breccia composed of shreds and patches of the invaded rock scattered through the invading granite, until eventually connected areas of the sedimentary series disappear entirely and over hundreds of square miles the granite and granite-gneiss alone are seen, holding, however, in

[1] Communicated by permission of the Director of the Geological Survey of Canada.

almost every exposure inclusions which represent the last scattered remnants of the invaded rock.

In addition to these intrusions of Laurentian granite-gneiss, there occur in the area, also cutting the Grenville series, great intrusions of gabbro and great bodies of nepheline syenite.[1] These massive intrusions of gabbro are frequently intimately associated with and partly inclosed by bodies of amphibolite which are classed as belonging to the Grenville series. The whole forms a very complicated and, at the same time, a very interesting stratigraphical complex, as will be seen by consulting the Bancroft or Haliburton geological map sheets recently issued by the Geological Survey of Canada. The former sheet is also to be found accompanying the paper on this region which has recently appeared in the *Quarterly Journal of the Geological Society of London*.[2]

The inability to determine the origin and, therefore, the significance of the bodies of amphibolite which occur abundantly not only in this district, but everywhere throughout the Laurentian, has always proved to be one of the chief difficulties in the way of a correct interpretation of the geology of this system. The same difficulty has been met with in the case of these and allied rocks occurring elsewhere, as, for instance, the trap granulites of the Saxon Granulit Gebirge, or the amphibolites of the crystalline complex of certain portions of the Alps, the origin of which remained in doubt while the rocks with which they are associated had been definitely determined.

It is the purpose of the present paper to present briefly the results of a study of the genetic relations of the amphibolites of this particular area in the Canadian Protaxis.

The amphibolites in the area in question present a considerable variety in character and appearance but have as common characteristics a dark-gray to black color and a basic composition. Hornblende and feldspar, the latter chiefly plagioclase, are the chief constituents of the rock. Quartz, which is one of the commonest constituents

[1] See Adams and Barlow, "The Nepheline and Associated Alkali Syenites of Eastern Ontario," *Transactions Royal Soc. Can.*, 1908.

[2] F. D. Adams, "The Laurentian System in Eastern Canada," *Q. J. G. S.*, 1908, p. 127.

in the associated gneisses, is absent or is present only in very small amount. Pyroxene or biotite often replaces the hornblende in part. The amphibolites are sometimes rather coarse, but usually medium or fine in grain, and they possess as a general rule a more or less pronounced foliated structure. They occur, as has been mentioned, associated, on the one hand, with the gabbro or diorite intrusions and as inclusions abounding throughout the granite of the bathyliths, and on the other hand they are often so intimately associated with certain developments of limestone in the form of interbedded layers that it has been found necessary to map the two rocks together and to designate them by a single color.

Two of the more common varieties of these amphibolites which occur associated with the limestones were, during the course of mapping, designated as "feather amphibolite" and "granular amphibolite." The first of these always occurs in thin bands interstratified with the limestone and derives its name from the curious feather-like development displayed by the large skeleton crystals of hornblende or pyroxene which are developed in the plane of the stratification of the rock and which give to the rock a striking appearance when it is split in this direction. The granular amphibolite, which also frequently occurs as heavy bands in the limestone, is of a finely granular character, without any very distinct foliation, and on the weathered surface presents a uniformly minutely speckled appearance, owing to the intimate admixture of minute grains of hornblende and feldspar.

As the result of a very careful examination, it is possible to prove conclusively that in this area the amphibolites have originated in three entirely different ways, the resulting rocks, although of such diverse origin, often being practically identical in appearance and composition. This remarkable convergence of type, whereby rocks of widely different origin come to assume a practical identity of character, explains the difficulty which has been experienced up to the present time in arriving at a satisfactory conclusion concerning their genetic relations.

These three modes of origin are as follows:

1. By metamorphism and recrystallization of impure calcareous sediments.

2. By the alteration of basic dykes and similar igneous intrusions.

3. By the alteration of limestone through the action of the intruding bathyliths of granite.

*First mode of origin.*—Some of these amphibolites result from the metamorphism and recrystallization of sediments. To this class belong the "feather amphibolites" above referred to, which usually occur in thin bands alternating with crystalline limestone and evidently of like origin. They represent siliceous, argillaceous, and dolomitic laminae in the original calcareous deposit. In many cases the bands of crystalline limestone become thinner and less abundant and the composite rock gradually passes over into a body of pure "feather amphibolite." This rock can, in certain parts of the area, be traced into a comparatively unaltered variety, so that its original character is definitely determinable. Whether the "granular amphibolite," which is also found very frequently and over wide areas alternating with bands of limestone, is in some cases of similar origin, it has not been possible up to the present time to determine.

*Second mode of origin.*—Certain granular amphibolites represent altered igneous intrusions, for they are found in the form of dykes cutting vertically across the stratified white crystalline limestone on the shores of Jack's Lake in the township of Methuen. The limestones here dip at a low angle to the south and are excellently exposed in the form of low cliffs about the side of the lake. The typical granular amphibolite can be seen rising above the surface of the water in the form of vertical dykes, cutting directly across the stratification of the limestone. These are one to two feet wide and can frequently be seen on reaching a certain bedding plane to have been bent over in the direction of the bedding which they follow, and to have been torn apart by movements in this plane, the limestone strata having, during their upheaval, experienced somewhat extensive movements along their bedding planes. The dykes, after having followed the bedding plane for a certain distance, once more cut vertically across the latter and so reach the surface. Such dykes when seen on limited exposure of the bedded surface of the limestone, especially in contorted districts, would usually present the appearance of interstratified masses of amphibolite.

This amphibolite has the regular allotriomorphic structure of a

completely recrystallized rock and differs from any of the normal igneous rocks. Under the microscope it is identical with an amphibolite described by Teall which was developed by the alteration of a diabase dyke where crossed by a line of shearing. In the case of these Canadian dykes, however, the amphibolite is not confined to that portion which has been clearly subjected to movement but forms the whole mass of the dyke. Seeing that this typical granular amphibolite can be proved to have originated from the alteration of a basic igneous dyke—in all probability originally a diabase—it is very highly probable that many other occurrences of this rock whose origin cannot be determined from their field relations may also be derived from the metamorphism of similar igneous intrusions.

*Third mode of origin.*—Amphibolites which are identical in physical character and in composition with those of class two are also produced by the metamorphic action exerted by the granite bathyliths on the limestones through which they cut. This is a remarkable fact and one which at first sight seems scarcely credible. It is, however, a change which has undoubtedly taken place on a large scale. The discovery that amphibolite originated in the manner just referred to explains what was a very puzzling fact in the early stages of the field-work in this region, namely, that while the granite bathyliths break through the limestone in all directions, they were filled with amphibolite masses and not with limestone inclusions. This fact was at first thought to be due to the granite happening to intrude portions of the limestone bands which were impure and thus held within themselves the material for the production of amphibolite by diagenetic rearrangment; but as occurrence after occurrence over the whole vast area was found to present the same phenomenon, it became evident that it was impossible to consider that the limestone strata had always happened to be impure at the places where the granite had broken through them, while elsewhere over great tracts the limestone contained little or no impurity. A critical study was therefore made of certain localities where the contact of the two rocks was well exposed and where the effects of the intrusion could be studied over a considerable range of country. This study showed conclusively that the limestone along its contact with the granite became impure through the development in it of bisilicates and plagioclase feldspar, and eventually when in

actual contact with the intruding rock that the limestone was changed into an amphibolite.

In addition to the amphibolites originating in the three ways above mentioned, it is highly probable, judging from their character and mode of occurrence, that the great amphibolite bands associated with large gabbro and diorite masses, as for instance that running in a northeasterly and southwesterly direction through the township of Wollaston, and that occurring in the southeast portion of the township of Cardiff, thence crossing Chandos into Anstruther, represent chiefly highly altered basic volcanic ashes and lava flows connected with vents represented by the gabbro stocks. The latter of these amphibolite bands presents a great variation from place to place in the character of the constituent rock. While in some places this amphibolite is well banded, elsewhere it is streaked or presents an appearance strongly resembling flow structure, with lighter colored, lathlike forms thickly scattered through it which are highly suggestive of feldspar phenocrysts, while elsewhere again it presents an appearance suggestive of an original amygdaloidal structure. The rock, however, is so completely recrystallized that a microscopic examination does not yield any conclusive evidence concerning its original character.

That amphibolites do originate in the first manner described is clearly seen and easily understood, and that they originate in the second manner referred to is well known and has been described in many localities, but that they may originate also in the third way above mentioned is not so generally recognized, and this mode of origin therefore merits a further consideration.

### DEVELOPMENT OF AMPHIBOLITE AS ONE OF THE CONTACT PHENOMENA ABOUT THE BORDERS OF THE GRANITE BATHYLITHS

About the borders of the various areas of granite, contact action is pronounced and often very striking. If the invaded rock be amphibolite, fragments torn from it are found scattered about in the gneiss, in the form of inclusions.

When the granite invades bodies of limestone, on the other hand, the phenomena resulting from the intrusion are more varied. The invading rock metamorphoses the limestone and the products of alteration may be divided into three classes:

*a*) The alteration of the limestone into masses of granular greenish pyroxene rock, usually containing scapolite, or into a rock consisting of a fine-grained aggregate of scales of a dark-brown mica.

*b*) Intense alteration of the limestone along the immediate contact into a pyroxene gneiss or an amphibolite.

*c*) In addition to these alteration products, in certain cases the granite dissolves or digests the invaded rock, after having altered it in one or other of the ways above mentioned.

The alteration products of Class *a* may be considered as due to the heated waters or vapors given off by the cooling magma, that is to be of pneumatolitic origin, while the alteration products of Class *b* result from the more immediate action of the molten magma itself. The products of these two classes of alteration, however, have much in common and naturally pass into one another.

The most common product of the alterations of Class *a* is a granular pale-green pyroxene rock which occurs in the limestone at or near the contact with the granite. This pyroxene rock, resulting from the alteration of the limestone, varies considerably in texture from place to place, but is usually medium in grain and granular in character, the sahlite individuals of which it is composed being short and stout with a hypidiomorphic development. Associated with the pyroxene in this rock are black mica, hornblende, scapolite, epidote, garnet, sphene, spinel, zircon, tourmaline, pyrrhotite, pyrite, molybdenite, calcite, apatite, and occasionally quartz and feldspar, as accessory constitutents. Of these minerals the mica and hornblende especially have a tendency to occur in segregations or nests composed of very large individuals, so large in fact that the mica has been mined in these pyroxene rocks at several places in the area, in one case mica crystals, having cleavage surfaces measuring two feet by two feet and a half, having been obtained. The calcite, when present in the rock, is usually in the form of very coarsely crystalline aggregates, cementing the other constituents together and into which the other minerals grow in the form of perfect crystals with excellent terminations. This calcite represents portions of the original limestone which have survived in an unaltered condition, except that they have grown more coarsely crystalline. When the calcite is subsequently removed in solution by percolating waters, spaces result which when

broken into by mining are found to be lined with beautiful crystals of pyroxene or other constituents of the rock.

The other product of pneumatolitic action belonging to this class is a rock composed of an aggregate of small leaves of a very deep brown or black mica, and is less common. These mica rocks almost invariably contain more or less calcite disseminated through them, which on exposure to the weather is dissolved out, the weathered surface of the rock thus being disintegrated into a soft mass of small scales of mica. The chemical nature of this mica has not been determined, but it is probably a variety of lepidomelane, containing a considerable amount of fluorine and probably some lithia such as is found in limestones about granite intrusions in other parts of the world.

The alterations of Class *b*, whereby the limestones are converted into amphibolite, are especially well seen about the borders of the great Glamorgan bathylith whose eastern limit lies in the township of Glamorgan. This bathylith here breaks through the great body of limestone underlying the northwestern portion of the township of Monmouth and affords a most excellent and striking example of *lit-par-lit* injection. The character of this contact action can be excellently studied at Maxwell's Crossing, on Lot 15 of Range VI of the township of Glamorgan. Here the limestone, toward the granite contact, passes gradually over into amphibolite, the latter being undoubtedly produced by the alteration of the former. The invading granite in the form of apophyses wanders through the limestone series in all directions, sometimes cutting across the bedding, but very frequently in the form of narrow dykes forcing their way between the beds of the invaded limestone, changing it into amphibolite and presenting a typical instance of *lit-par-lit* injection. The granite, furthermore, not only penetrates the series, but floats off masses of the altered rock which, in the form of bands, streaks, and isolated shreds, are seen thickly scattered through the granite in the vicinity of the contact, and which, while less abundant, are found throughout practically the whole extent of this bathylith as mentioned below. The separate fragments of amphibolite where completely surrounded by the granite, while clearly nothing more than masses of altered limestone, are rather harder and more "granitized" in appearance than the amphibolite which is still interstratified with the limestone, and the

fragments sometimes have somewhat flowing outlines as if they had been subjected to a certain amount of movement when in a softened condition.

When examined in thin sections under the microscope the limestone which is in the act of passing into amphibolite is seen to do so by the development in it of certain silicates. These, when the change is complete, are so abundant that they have entirely replaced the calcite while in the intervening stages some of the original calcite still remains. These silicates belong to the following species: Pyroxene, hornblende, sphene, scapolite, plagioclase, microcline, orthoclase, and quartz. The relative abundance of these minerals varies in different bands and from place to place in the rock. Their characters are as follows.

The *Pyroxene* is rather deep green in color and shows an absence of pleochroism. It is one of the chief constituents, being in the earlier stages of the change present in large amount. It first appears in individuals which are rounded in shape, do not possess crystallographic outlines or any approximation to crystalline form. In those varieties rich in calcite, the sections of the pyroxene grains are frequently nearly circular.

The *Hornblende*, which at first is much less abundant than the pyroxene, is also green in color but it is a much deeper green than the pyroxene. The grains are similar to those of the pyroxene in form, but are usually less rounded. It is intimately associated with the pyroxene, often forming adjacent grains, but there is no conclusive evidence that one mineral is derived from the other. It is strongly pleochroic.

The *Sphene* is present only in a very small amount in the form of small rounded grains of a brown color.

*Scapolite* is usually present in considerable amount. It polarizes in brilliant colors, is uniaxial and negative, and shows the other microscopical characters of this mineral.

The *Feldspars* vary greatly in amount. In places they form a considerable part of the rock, while no scapolite is present. In other places the scapolite seems to take their place and they are reduced to the rank of accessory constituents, All three varieties of feldspar mentioned often occur in the same specimen, their relative

abundance varying from slide to slide. The polysynthetically twinned plagioclase in some cases equals the potash feldspar in amount, but usually the potash feldspars seem to be rather more abundant.

The *Quartz* is found only in a few of the thin sections and is there present only in very small amount.

When the *Calcite* survives, it can be seen that the original rock had the character of a coarsely crystalline limestone or marble. Under the action of the metamorphic processes the silicates have grown into it in the form of rounded grains which, increasing gradually in size, have finally left the calcite merely as a filling of the surviving interstitial spaces. The grains are about the same size as those of the other minerals.

An examination of thin sections of a suite of specimens of this amphibolite from a single series of exposures in the cutting on the line of the Irondale, Bancroft and Ottawa Railway at Maxwell's Crossing—some of them still containing little surviving bands of calcite and others of the harder and more altered varieties—shows that in the former pyroxene and scapolite accompany the hornblende and feldspars, while as the alteration becomes more pronounced these former minerals become less abundant and eventually disappear, giving rise to a rock composed of hornblende and feldspar, associated with which a little biotite is seen in some specimens, with certain accessory minerals which are common to both rocks. Although, as above mentioned, no actual passage of pyroxene into hornblende could be definitely observed, the hornblende individuals often have a minutely serrated edge where they come against the pyroxene, as if they were gradually enlarging themselves at the expense of the latter mineral and thus replacing it.

The amphibolite, representing the final product of the alteration, while possessing a more or less distinct foliation, has the "pflaster," "pavement," or mosaic structure characteristic of rocks which have resulted from recrystallization brought about by metamorphic processes. It presents no evidence of crushing or of having been caused to move since its recrystallization took place. This structure is quite distinct and different from that seen in the little injected bands of granite. In these, which are composed of quartz, microcline, orthoclase, and plagioclase, the quartz occurs for the most part in thin leaves with

undulatory extinction and the structure of the rock is suggestive of the "mortel" or granulated structure seen in the granite gneisses.

In this remarkable occurrence, therefore, the crystalline limestone can be seen under the influence of the granite intrusion to have changed into a typical hornblende feldspar amphibolite, having passed through the intervening stage of a pyroxene scapolite hornblende feldspar amphibolite (pyroxene scapolite gneiss).

Three specimens of these amphibolitic rocks from Maxwell's Crossing, chosen to represent three steps in the progressive change from limestone to amphibolite, were selected for analysis. The analyses were made by M. F. Connor, B.Sc., of the Geological Survey of Canada. The figures given are in every case the mean of two determinations which agree closely with one another. The results of these analyses are as follows:

| | No. 1 | | No. 2 | No. 3 |
|---|---|---|---|---|
| | (*a*) | (*b*) | | |
| $SiO_2$ | 32.88 | 50.20 | 50.00 | 50.83 |
| $TiO_2$ | 0.49 | 0.75 | 0.82 | 1.10 |
| $Al_2O_3$ | 9.04 | 13.80 | 18.84 | 18.64 |
| $Fe_2O_3$ | 0.77 | 1.18 | 2.57 | 2.84 |
| FeO | 3.48 | 5.31 | 5.51 | 5.97 |
| MnO | ..... | ..... | 0.08 | 0.10 |
| CaO | 30.90 | 17.71 | 10.65 | 7.50 |
| MgO | 4.18 | 6.38 | 4.63 | 4.90 |
| $K_2O$ | 0.85 | 1.30 | 1.18 | 1.83 |
| $Na_2O$ | 1.17 | 1.79 | 4.46 | 4.22 |
| $CO_2$ | 15.20 | ..... | 0.10 | 0.11 |
| Cl | undet. | ..... | 0.10 | 0.03 |
| S | undet. | ..... | 0.03 | 0.01 |
| $H_2O$ | 1.08 | 1.66 | 1.00 | 1.40 |
| | 100.04 | 100.08 | 99.97 | 99.48 |

No. 1 represents the first stage of alteration and was made from a specimen which shows an alternation of narrow lighter and darker colored bands. The specimen was broken across the strike of the rock and thus included several of each of these bands, giving in this way an approximate average of the composition of the rock as a whole. Under the microscope the lighter colored bands are seen to consist of calcite, pyroxene, and a little hornblende. In the darker bands the calcite is largely replaced by the silicates, the constituent minerals

of these bands being scapolite, pyroxene, some hornblende, some calcite, and a little microcline. A very small amount of sphene is also present in the rock.

The analysis as given under No. 1 *a* represents the composition of the specimen as collected; that given under No. 1 *b* represents the composition of the rock as it appears when the calcite present (determined by calculation from the amount of $CO_2$ present and also by direct experiment) is deducted and the amount of the remaining constituents is recalculated on the basis of 100. No. 1 *b* therefore represents the percentage composition of the silicated portion of the specimen, or, to put it in another way, it represents, except in the case of the lime, the additions made to the limestone by the granite magma in this first stage of alteration. The specimen contains 34.50 per cent. of calcite, leaving 65.50 per cent. of silicates. This silicated portion of the rock, as will be seen by comparing analysis No. 1 *b* with Nos. 2 and 3, bears a general resemblance in composition to the two latter rocks which represent the subsequent stages of alteration, the percentage of silica being practically identical in all cases.

No. 2 is the analysis of a typical specimen of the amphibolite which alternates with thin bands of the limestone at Maxwell's Crossing. It represents a second stage in the alteration, this particular specimen being practically free from calcite. Under the microscope it is seen to be composed of hornblende and pyroxene, more or less completely replacing each other in the alternate bands, together with a considerable amount of scapolite, plagioclase and untwinned feldspar. The rock also contains many minute rounded grains of sphene scattered everywhere through it, but holds no iron ore and no biotite.

No. 3 is the analysis of a harder variety, being a typical amphibolite and representing the last stage of the change. It occurs as an inclusion in the granite in the same series of exposures as that from which the other specimens were taken. The field relations show that it has been derived from variety No. 2 by further alteration. Although not differing much from No. 2 in chemical composition, under the microscope it is seen to differ considerably from it in structure, the individuals of the several constituents showing a less marked tendency to a rounded outline than in the case of No. 2. In mineralogical composition also it presents certain differences, the pyroxene and

scapolite having disappeared and a certain amount of biotite having been developed.

A comparison of the analyses shows that the granite at first transfuses into the limestone, silica, alumina, oxides of iron and magnesia, with some alkalis and a small amount of titanic acid. As the alteration progresses, all these constituents continue to increase in amount. But in these later stages of the alteration the alumina, oxides of iron, and alkalis are added in relatively greater proportion than the other constituents, while no further addition of magnesia or lime takes place, the proportion of these constituents remaining essentially the same, the carbonic acid escaping and carrying the rest of the lime with it.

This means, speaking generally, that pyroxene and some scapolite were first developed in the limestone and that later the feldspathic constituents increased in amount, the calcite present being removed in solution.

A calculation of the analyses shows that Nos. 1 *b* and 2 have the following mineralogical composition:

| | No. 1 *b* | No. 2 |
|---|---|---|
| Feldspathic constituents | 48.57 | 67.35 |
| Pyroxenic (iron magnesia) constituents | 46.63 | 26.28 |
| Iron ores | 3.2 | 5.27 |
| | 98.40 | 98.90 |
| Water | 1.66 | 1.00 |
| | 100.06 | 99.90 |

During the change of No. 1 into No. 2 and this into No. 3, the information afforded by the analyses bears out that obtained from the study of the thin sections, showing that there has been a very considerable rearrangement among the constituents of the rock. Thus it is seen that while the alumina and alkalis increase in No. 2 and No. 3, there is not a corresponding increase in the total amount of silica; the silica required to make additional feldspathic constituents being derived from some other reactions going forward in the rock.

It seems also that after the development of a certain percentage of silicates in the limestone, as shown in No. 1, during which process

carbonic acid was expelled and the lime combined with it used in the production of new minerals, no further lime was fixed. In the earlier stages the waters given off by the granite having accomplished the transference of material into the limestone, passed off with the replaced $CO_2$ in solution, leaving the lime behind. In the later stages of the alteration, however, these waters, while continuing to deposit silicates in the limestone, made place for these latter by carrying off carbonate of lime in solution.

As will be seen, the difference in chemical composition between Specimen 2 and Specimen 3 is very small. The more highly altered rock, No. 3, is rather richer in iron, magnesia, and alkalis, while it is considerably poorer in lime and contains less chlorine. These differences are seen to represent a slight increase in the proportion of hornblende and orthoclase present and a decrease in the amount of plagioclase and scapolite in the rock.

If, for the purpose of comparing the composition of these alteration products with that of igneous rocks, the norms are calculated, these are found to be as follows. Since No. 3 is essentially the same as No. 2, the norm of the latter rock may be taken to represent both specimens and with it is given the norm of the silicated portion of No. 1 (No. 1 *b*).

| | No. 2 | No. 1 *b* |
|---|---|---|
| Orthoclase | 7.23 | 7.74 |
| Albite | 26.20 | 15.24 |
| Anorthite | 27.94 | 25.59 |
| Nepheline | 5.56 | ..... |
| Sodalite | 0.42 | ..... |
| Diopside | 19.78 | 34.81 |
| Akermanite | ..... | 6.97 |
| Olivine | 6.30 | 4.85 |
| Calcite | 0.20 | ..... |
| Ilmenite | 1.52 | 1.40 |
| Magnetite | 3.71 | 1.80 |
| Pyrite | 0.04 | ..... |
| | 98.90 | 98.40 |
| Water | 1.00 | 1.66 |
| | 99.90 | 100.06 |

In the quantitative classification the rocks, therefore, have the following position:

| No. 2. | | No. 1 *b* | |
|---|---|---|---|
| Class II | Dosalane | Class III | Salfemane |
| Order 5 | Germanare | Order 5 | Gallare |
| Rang 3 | Andase | Rang 4 | Auvergnase |
| Subrang 4 | Andose | Subrang 4 | Auvergnose |

While, therefore, the quantitative classification is intended to apply only to igneous rocks, this final product of the metamorphism of the limestone when compared with igneous rocks readily takes its place as an andose, a group which includes many rocks which are commonly known as diorites, gabbros, basalts, diabases, and essexites.

For purposes of comparison the analysis of this amphibolite (No. 2) is here repeated together with that of an amphibolite (No. 5) produced by the alteration of a basic igneous intrusion (probably a diabase originally) and with the analyses of three typical igneous rocks which have been produced by the solidification of molten magmas.

| | No. 4 | No. 5 | No. 6 | No. 7 | No. 8 |
|---|---|---|---|---|---|
| $SiO_2$ | 50.00 | 48.81 | 50.86 | 50.73 | 48.85 |
| $TiO_2$ | 0.82 | 0.74 | .... | 1.59 | 2.47 |
| $Al_2O_3$ | 18.84 | 16.62 | 15.72 | 19.99 | 19.38 |
| $Fe_2O_3$ | 2.57 | 1.17 | 9.77 | 3.20 | 4.29 |
| FeO | 5.51 | 7.47 | 2.48 | 4.66 | 4.94 |
| MnO | 0.08 | 0.12 | .... | 0.05 | 0.19 |
| CaO | 10.65 | 10.30 | 10.52 | 8.55 | 7.98 |
| MgO | 4.63 | 8.28 | 3.55 | 3.48 | 2.00 |
| $K_2O$ | 1.18 | 0.76 | 0.90 | 1.89 | 1.91 |
| $Na_2O$ | 4.46 | 3.31 | 3.89 | 4.03 | 5.44 |
| $CO_2$ | 0.10 | 0.55 | .... | .... | .... |
| Cl | 0.10 | 0.03 | .... | .... | not det. |
| S | 0.03 | 0.06 | .... | .... | .... |
| $P_2O_5$ | .... | .... | .... | 0.81 | 1.23 |
| $H_2O$ | 1.00 | 0.95 | 2.53 | 0.77 | 0.68 |
| | 99.97 | 99.17 | 100.22 | 100.13* | 99.36 |

* Including BaO 0.27.

No. 4. Amphibolite resulting from the alteration of limestone—Maxwell's Crossing—Lot 5, Range VI, Township of Glamorgan, Ontario.

No. 5. Dyke cutting limestone—Lot 27, Range VIII, Township of Methuen, Ontario.

No. 6. Gabbro, near Baptism River, Minnesota, U. S. A. (Wadsworth, *Geol. Survey of Minn.*, 2, p. 79, 1887).

No. 7. Diorite—Big Timber Creek, Crazy Mountain, Montana (Wolff, *Bull. U. S. G. S.*, 148, p. 144, 1897).

No. 8. Normal Essexite—Mount Johnson, Quebec (Adams, *Jour. of Geol.*, April-May, 1903).

The silicated portion of the half-altered limestone (Analysis 1 *b*), which in the quantitative classification would fall under Auvergnase, has certain igneous rocks which approach it rather closely in composition, although it is higher in lime than any igneous rock whose analysis has been hitherto recorded, as emphasized by the fact that akermanite appears as a standard mineral in its norm. The following igneous rocks resemble it most closely:

| | I | II | III |
|---|---|---|---|
| $SiO_2$ | 48.11 | 46.15 | 46.16 |
| $Al_2O_3$ | 16.98 | 13.57 | 13.86 |
| $Fe_2O_3$ | ..... | 3.61 | 5.26 |
| FeO | 7.82 | 8.15 | 1.81 |
| MnO | 1.88 | ..... | ..... |
| MgO | 5.67 | 12.63 | 11.60 |
| CaO | 17.75 | 15.15 | 15.74 |
| $Na_2O$ | 1.82 | 1.29 | 1.05 |
| $K_2O$ | ..... | ..... | 0.30 |
| $H_2O$ | ..... | ..... | 3.40 |
| | 100.03 | 100.55 | 99.18 |

I. Saussurite gabbro, Yttero, Norway.

II. Hypersthene gabbro, Urals, Russia (Loewinson-Lessing, *G. Sh. Jushno Saos*, Dorpat, 1900, p. 166).

III. Gabbro (not fresh), Laurion, Greece (R. Lepsius, *Geol. v. Attika*, Berlin, 1893, p. 98).

In connection with this alteration of limestone to amphibolite it is to be noted that the change is not one of solution or digestion of the limestone by the granite, for the fragments preserve their sharp and well-defined forms even when the alteration is complete.

The limestone, at a distance from the granite, is a white crystalline marble, containing scarcely any impurities and effervescing freely in fragments with cold dilute hydrochloric acid, showing that it is an essentially pure carbonate of lime.

The granite which brings about this alteration has not been analyzed but is in all probability of essentially the same composition

as that of the adjacent Methuen bathylith, the analysis of which is given below:

| | | | |
|---|---|---|---|
| $SiO_2$ | 73.33 | CaO | 1.66 |
| $TiO_2$ | 0.17 | MgO | 0.45 |
| $Al_2O_3$ | 13.55 | $K_2O$ | 3.12 |
| $Fe_2O_3$ | 0.58 | $Na_2O$ | 5.01 |
| FeO | 1.53 | $H_2O$ | 0.45 |
| MnO | 0.04 | | 99.89 |

The changes are the result of the transfusion into the limestone of certain constituents which are present in the granite magma. A remarkable fact in connection with the alteration, is that the granite, which is an acid variety of the rock containing a very small amount of biotite as its only bi-silicate, where the limestone was bathed by it or actually immersed in it as in the case of the included fragments, has notwithstanding this fact transfused into the limestone not only silica, alumina, and alkalis, as might be expected, but also large amounts of magnesia and iron. The limestone evidently fixed certain constituents of the granite magma in relatively greater abundance than others, exerting a species of selective action. Many cases have been described in which a granite magma has passed by differentiation into a gabbro, but here the granite retains its normal character and at the same time changes the limestone into a rock having the composition of a gabbro.

That similar changes are brought about by the action of acid magmas upon limestones elsewhere is shown by two occurrences described by Kemp[1] and one by Lindgren. The first is from San José, in the State of Tamaulipas, Mexico, the second from Morenci, Arizona, and the third from White Knob, Idaho. In all cases highly acid intrusive rocks, quartz-porphyries or quartz-diorite-porphyries, very low in iron, penetrate limestones which are so pure that they can yield little or no garnet of themselves. In each case the intrusives

[1] J. F. Kemp, "Ore Deposits at the Contacts of Intrusive Rocks and Limestones and Their Significance as Regards the General Formation of Veins," *Economic Geology*, Vol. II, No. 1, 1907, p. 1, and *Trans. Am. Inst. Mining Eng.*, XXXVI, p. 192. W. Lindgren, *U. S. Geological Survey*, Professional Paper No. 43, p. 134. See also O. E. Le Roy, "The Marble Bay Copper District," *Jour. Can. Min. Inst.*, 1907, p. 248.

have developed in the limestones large amounts not only of an alumina garnet (grossularite), but also of an iron garnet (andradite), showing that the acid magma has transfused into the limestones large amounts of $SiO_2$, $Al_2O_3$, and $Fe_2O_3$, which the limestones have fixed in the form of garnet.

Kemp's conclusions concerning these occurrences exactly coincide with those reached from a study of the occurrences in the Haliburton-Bancroft area, as shown by the following quotations from the paper referred to above:

> First of all the question may be raised as to whether the eruptive has melted into its substance sufficient limestone to yield the zones which have then crystallized out from fusion. This view is opposed both by the sharp contacts afforded by the eruptive against the garnet zones; by the variability of the zones in mineralogy, and by the fact that the necessary ingredient of andradite would not thereby be afforded. In almost all cases the eruptive is a highly acidic rock, a quartz-porphyry, or quartz-diorite-porphyry. The percentage in iron is very small, far below the requirements of the iron-lime garnet, and the general composition not at all adapted to yield the zones. On the contrary we are irresistibly led to the conclusion that from the intrusive rock has come either highly heated water gas or highly heated water itself in the closing stages, and that one or both of these have brought to the limestone the silica, iron oxide, and alumina for the production of the lime-silicates. After the production of the garnet and its associates was well under way, they brought in also the copper and iron sulphides which are the commonest ores.
>
> The silica and the other dissolved materials did not wander farther from the eruptive because the limestone promptly intercepted them and locked them up in silicates; but undoubtedly carbonated water and carbon dioxide gas were yielded in great quantity, an inference which falls harmoniously in line with what we know of volcanic emissions.

# A MIOCENE FLORA FROM THE VIRGINIA COASTAL PLAIN[1]

EDWARD W. BERRY
Johns Hopkins University

The later Tertiary of Europe is as remarkable for its extensive and representative floras, as is that of America for their absence, for with the exception of certain isolated florules of the Western Interior and Pacific coast region there are no known Miocene floras in America.

The Atlantic coastal plain Miocene, or Chesapeake Group, appears to be made up entirely of marine deposits carrying an abundant, chiefly molluscan fauna and furnishing but slight hints of the life which flourished along its shores. It has been correlated on the basis of its invertebrates by Dall and others with the Helvetian or Middle Miocene of Europe. The earliest member of the Chesapeake Group, the Calvert formation, is characterized in the Maryland-Virginia region by extensive beds of diatomaceous earth which rest with marked unconformity on the usually glauconitic sands of the Eocene or overlapping them to a notable extent in Virginia.[2]

While the Miocene of the world was in general a period of elevation it would seem as if this elevation was greatest in eastern North America in the interval which preceded the deposition of the Chesapeake Group, during which time the Eocene appears to have undergone great denudation, since the comparative purity of the diatomaceous beds of the Calvert formation seems to have been due to the lowness rather than to the remoteness of the adjacent mainland with the consequent lack of erosion. This supposition is fully borne out by the evidence of the flora discussed in the following pages.

Some years ago the Maryland Geological Survey discovered plant remains in the Calvert formation as exposed on Good Hope Hill which is situated in the District of Columbia just across the Anacostia

[1] Published by permission of the Director of the U. S. Geological Survey.

[2] They of course rest on the older Cretaceous or the underlying crystallines in places where the Eocene is absent.

River from Washington. These were few and rather poor, but sufficient to form the basis for six species, all new, which were described by Dr. Arthur Hollick[1] in 1904. It is probable that an exhaustive search would disclose similar remains elsewhere in this immediate region, since the writer has seen fragmentary plant fossils from these same beds along the Bennings road near the District lines, and from the banks of the Choptank River and Tuckahoe Creek, on the Eastern Shore of Maryland. The only other eastern flora of possible Miocene age is that from the Bridgeton gravels of southern New Jersey which is understood to be quite extensive.[2] It also has been studied by Dr. Hollick but is as yet unpublished. It is considerably younger, however, than that of the Calvert formation and may possibly be of Pliocene age.

With these preliminary remarks we turn to a very interesting flora found in the Calvert formation at Richmond, Virginia. The presence of this flora was discovered by Dr. Benjamin L. Miller during a reconnaissance trip in 1906, but no collections were made until the present summer when the writer spent part of two days in making a thorough collection at this locality and it is upon this collection that the following notes are based. The Calvert formation at this point consists of very argillaceous diatomaceous earth forty to fifty feet in thickness, resting unconformably upon remnants of the Eocene or upon the underlying crystallines and overlain by Pleistocene deposits. That this locality was near the shoreline of the Miocene sea, as it is near the landward limit of the existing Calvert deposits, is indicated not only by the argillaceous nature of the materials as compared with similar diatomaceous deposits elsewhere in the Calvert formation, but by the contained plant fossils, as well as by considerable comminuted lignite, the latter forming layers 5–12 mm. thick in places.

Thirteen species are enumerated in the present communication and the doubtful fragments uncharacterized at this time include perhaps two or three more forms in addition to several varieties of seeds not yet identified. The species recognized include seven well-known and widespread Tertiary forms and one species, *Rhus milleri*

[1] Hollick, "Miocene," *Maryland Geol. Surv.*, 1904, pp. 483–86, Figs. *a–h*.

[2] A Miocene flora of considerable variety and extent, discovered within the last few months in North Carolina, is being studied by the writer at the present time.

Hollick, previously described from the Calvert formation of Maryland. Six species are described as new.

It seems evident that this is a localized flora and not one characteristic of the eastern American uplands during Miocene time, and we may compare the local conditions at that time with those which exist at the present day in the Dismal Swamp region, or, better still, with the innumerable cypress swamps which skirt the South Atlantic coast. There is the Miocene cypress (*Taxodium*) by far the most abundant fossil in these deposits and associated with it we find *Salvinia*, a floating plant in the modern flora. The seeds of a *Nyssa* represent that modern semi-aquatic genus. *Carpinus* and *Planera* are both low swamp and waterside types at the present day, as are a majority of the willows (*Salix*). *Platanus* inhabits wet situations as do also several species of *Fraxinus* and many species of *Ficus*. The oak (*Quercus*) is at home in the environment pictured, while the *Rhus*, *Celastrus*, and the two species of Leguminoseae are not at all out of place in such an association. The conclusion seems irresistible that in these fossiliferous Calvert deposits we have preserved some of the débris of a nearby cypress swamp, and that it was the presence of such swamps along the consequently low-lying coast where the streams were of necessity inactive, which effectually prevented any large amount of land-derived sediment from becoming a part of the Calvert formation. Citations are restricted to the more important references in the following notes:

**Subkingdom Pteridophyta**
Order FILICALES
Family *Salviniaceae*
Genus Salvinia Adans
SALVINIA FORMOSA Heer?

*Salvinia formosa* Heer, Fl. Tert. Helv., 3:156. pl. 145. f. 13–15. 1859.
Velenovsky, Fl. Ausgebr. Tert. Letten v. Vrsovic, 12. pl. 1. f. 14–17. 1882.
Hollick, Bull. Torrey Club, 21:256. pl. 205. f. 6. 1894.
Zeiller, Fl. Foss. Gites de Charbon du Tonkin, 269. pl. 51. f. 2, 3. 1903.

This undoubted fragment of a Salvinia leaf has been doubtfully referred to the above species, with which it agrees in so far as its characters can be made out, rather than to adopt the course of founding a new species upon a single fragmentary specimen. Future

collections may furnish sufficient material for a complete diagnosis in which case the specific identity can be positively settled.

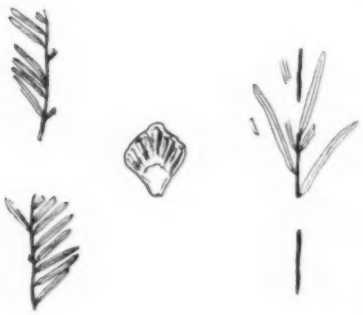

FIG. 1

**Subkingdom Spermatophyta**
Class GYMNOSPERMAE
Order CONIFERALES
Family *Pinaceae*
Subfamily *Taxodieae*
Genus Taxodium Rich.
TAXODIUM DISTICHUM MIOCENUM
Heer

*Taxodites dubius* Sternb., Fl. d. Vorwelt, 204. 1838.
Unger, Iconogr., 20. pl. 10. f. 1–7. 1852.
*Taxodium dubium* Heer, Fl. Tert. Helv., 1:49. pl. 17. f. 5–15; 1855.
*Taxodium distichum miocenum* Heer, Mioc. Baltic Fl., 18. pl. 2; pl. 3. f. 6, 7. 1869.
Newb., Mon. U. S. Geol. Surv., 35:22. pl. 47. f. 6; pl. 51. f. 3; pl. 52. f. 2–4; pl. 55. f. 5. 1898.
Knowlton, Bull. U. S. Geol. Surv., No. 204:27. 1902.
Harriman Rept., 4:152. 1904.

This is by far the commonest fossil in these deposits indicating that the nearby shores were probably bordered by cypress swamps, thus furnishing a plausible explanation for the absence of terrigenous materials in the Calvert formation.

It is an exceedingly common and widespread Tertiary species ranging from the Eocene upward into the basal Pliocene (Messinian) and recorded from numerous localities throughout Eurasia from Japan and the Kirghiz Steppe to Italy, Prussia, France, and Switzerland. In the Arctic regions it has been found in Alaska, Grinnell Land, and Greenland, and in the United States it is recorded from Nevada, Wyoming, Montana, and Oregon.

It may be distinguished from the equally wide-ranging *Sequoia langsdorfii* by the markedly decurrent leaves of the latter.

The collection made at Richmond include, in addition to the leafy twigs, the characteristic cone-scale figured, which is slightly smaller than the usual scales of the existing species but otherwise exactly similar.

**Class Angiospermae**
Order SALICALES
Family *Salicaceae*
Genus Salix Linné
SALIX RAEANA Heer

FIG. 2

*Salix raeana* Heer, Fl. Foss. Arct., 1:102, 139. pl. 4. f. 11–13; pl. 21. f. 13; pl. 47. f. 11. 1868.
*Ibid.*, 2. ab. 4:469. pl. 43. f. 11a. 1871.
*Ibid.*, 4. ab. 1:70. pl. 14. f. 8. 1877.
*Ibid.*, 7:76. pl. 69. f. 2; pl. 86. f. 4. 1883.
Lesq., Proc. U. S. Natl. Mus., 11:17. 1888.
Knowlton, Bull. U. S. Geol. Surv., No. 204: 30. 1902.

The basal portions (about one-half) of two leaves of a Salix were found at Richmond, and, although incomplete, they agree so admirably with the numerous figures of this species given by Heer as to leave little doubt of their specific identity. They indicate a mediumly broad lanceolate leaf 3.5 cm. long by 1.3 cm. in greatest width, which was toward the somewhat rounded base.

This species was described originally from Greenland by Heer who afterward detected it in material from Spitzbergen, and in the Tertiary collection from near the north of the Mackenzie River made by Sir John Richardson's expedition. Lesquereux afterward identified it from the Mascall beds of Oregon, basing his determination upon material which Dr. Knowlton states (*loc. cit.*) is very poor and doubtful.

Order FAGALES
Family *Betulaceae*
Genus Carpinus Linné
CARPINUS GRANDIS Unger

*Carpinus grandis* Unger, Syn. Pl. Foss., 220. 1845.
Heer, Fl. Tert. Helv., 2:40. pl. 71. f. 19b–e; pl. 72. f. 2–24; pl. 73. f. 2–4. 1856.
Fl. Foss. Arct., 1:103. pl. 49. f. 9. 1868.
*Ibid.*, 2:469. pl. 44. f. 11c. 1871.
*Ibid.*, 3. ab. 2:14, 17. pl. 3. f. 14. 1874.
*Ibid.*, 7:82. pl. 88. f. 4, 5. 1883.
Lesq., Tert., Fl., 143. pl. 19. f. 9; pl. 64. f. 8–10. 1878.
Velenovsky, Fl. Ausgebr. Tert. Letten v. Vrsovic, 23. pl. 2. f. 25; pl. 3. f. 1–6. 1882.
Knowlton, Bull. U. S. Geol. Surv., No. 204:38. 1902.

This is another of those widespread Tertiary species which may be composite although usually regarded as simply a variable type. The Richmond collections contain eight fragments of leaves which are referred with some little hesitation to this species. The venation is similar, although it must be admitted that it would serve equally well for Fagus, Betula, Ostrya, or Planera; the variability in size is in accord with that usually observed in this species as is also the general outline. Unfortunately the marginal characters, while they suggest this form, are not well enough preserved to be decisive, all of the leaves being macerated in exactly the same manner as are the delicate leaves of *Carpinus caroliniana* Walt. after they have floated down our southern rivers for a considerable distance.

*Carpinus grandis* makes its appearance in the Arctic Tertiaries, becoming rather widespread before the close of the Oligocene and is recorded from Europe, Asia, and America. It is more especially, however, a Miocene type and has been collected from a large number of European localities as well as from Japan and the Mascall beds of the John Day basin in Oregon. It persists into the Pliocene, being recorded from beds of that age in Styria and in Italy (Messinian).

Family *Fagaceae*
Genus Quercus Linné
QUERCUS MILLERI sp. nov.

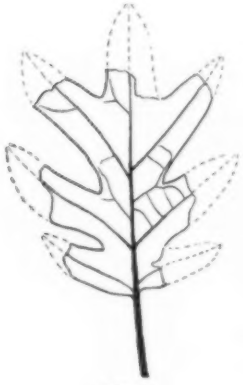

FIG. 3

Leaves about 5 cm. in length with a mediumly stout petiole 1.4 cm. long. Lobate, with three narrow rather obtusely pointed lobes on each side, each traversed by a prominent secondary whose angle of divergence is less than that of the lobes, the secondaries leaving the midrib nearly on a line with the basal margin of the lobes and running nearer their upper than their lower margin to the apex of the lobe. Basal lobes forming almost a right angle with the midrib, their lower margins being very obtusely rounded, almost truncated, to within a millimeter or two of the petiole and then curving slightly downward, their secondaries branching at an angle of 55° about one millimeter

above the top of the petiole, subopposite. The sinus which intervenes between the basal and the median lateral lobes is cut to within 4 or 5 mm. of the midrib and is narrow and acute and but slightly inclined. The median lateral lobes which are 50 per cent. longer than the basal pair, and also broader, are somewhat more ascending, the angle of divergence of their secondaries from the midrib being 46°. The next sinus is somewhat broader, widening out laterally. It is about the same depth as the lower sinus, terminating internally in a narrow obtuse point. The upper lateral lobes are about the same length as the median pair, but are more ascending, their secondaries diverging from the midrib at an angle of from 35° to 42°. The terminal lobe is 9 mm. wide at its base and of undeterminate length, probably about 1.5 cm., the sinus between it and the upper lateral lobes being broad and almost straight sided, terminating internally in an obtuse point. The leaf texture was somewhat coriaceous and the tertiaries were camptodrome and of the usual Quercus type.

This species is based upon two specimens with their counterparts, the more perfect of which is figured, the other being slightly larger and showing the obtuse terminations of the lobes, supplying these parts which are missing in the figured specimen.

This is a rather handsome oak abundantly distinct from the forms heretofore known, and it is named in honor of Dr. Benjamin L. Miller who discovered the locality from which the collections were made.

Order URTICALES
Family *Ulmaceae*
Genus Planera J. F. Gmelin
PLANERA UNGERI Ettings

FIG. 4

*Planera ungeri* Ettings., Foss. Fl. v. Wien, 14. pl. 2. f. 5–18. 1851.
Heer, Fl. Tert. Helv., 2:60. pl. 80. 1856.
Fl. Foss. Arct., 2:472. pl. 45. f. 5a, c; pl. 46. f. 6, 7a, 1871.
*Ibid.*, 5. ab. 6:53. pl. 15. f. 19; ab. 7:40. pl. 9. f. 10; pl. 10. f. 1, 2. 1878
*Ibid.*, 7:94. pl. 75. f. 11; pl. 89. f. 9; pl. 92. f. 9; pl. 95. f. 6. 7; pl. 97. f. 3. 1883.
Kovats, Foss. Fl. v. Erdöbénye, 27. pl. 5. f. 1, 2; pl. 6. f. 1–6. 1856.
Lesq., Tert. Fl., 190. pl. 27. f. 7. 1878.

Velenovsky, Fl. Ausgebr. Tert. Letten v. Vrsovic, 26. pl. 3. f. 18–23; pl. 4. f. 14. 1882.
Friedrich, Beitr, Tertfl. Sachsen, 164. pl. 26. f. 2, 3. 1883.
Knowlton, Bull. U. S. Geol. Surv., No. 204:55. 1902.

Fragments of this ubiquitous species are fairly common at Richmond, the one figured being the most definite. It indicates a somewhat more orbicular leaf than the majority of leaves of this species but may be compared with several Greenland leaves which Heer identifies as *Planera ungeri*.[1] The marginal teeth and venation are identical with those of more complete specimens from European Tertiary localities and the implied environmental conditions were also most suitable. There is some resemblance to the Mascall species *Betula ? dayana* of Knowlton[2] and also to the Tortonian *Betula weissii* Heer[3] of Europe.

*Planera ungeri* has a recorded range from the Eocene into the Pleistocene and a distribution from Manchuria and Japan through Asia and Europe to Colorado and Oregon, occurring also in Greenland and Iceland. It is quite possible that more than one species may be included under this name but if such is the case their proper segregation is still a task for the future.

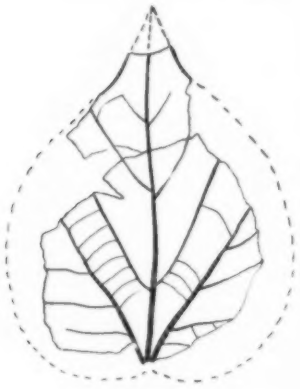

FIG. 5

Family *Moraceae*
Genus Ficus Linné
FICUS RICHMONDENSIS sp. nov.

Leaves apparently cordate in outline, about 5 to 6 cm. long by 5 cm. in greatest width, acuminate, entire. Venation palmate, the lateral primaries of somewhat less caliber than the midrib, from which they diverge at an acute angle (about 30°) at or near its base. The midrib gives off three pairs of secondaries above the lateral primaries

[1] Cf. Heer, Fl. Foss. Arct., 7. pl. 89. f. 9; pl. 95. f. 7. 1883.
[2] Knowlton, U. S. Geol. Surv., *Bull. No. 204*, 41, pl. 4, f. 4, 1902.
[3] Heer, Fl. Tert. Helv., 2:39, pl. 71, f. 24, 1856.

and these are apparently camptodrome. Tertiaries numerous, but slightly curved, transverse. Lateral primaries giving off externally three or four nearly straight branches.

The fossils, like the recent species of Ficus, are very numerous and range from the Cretaceous upward. The present species is based on the single imperfect specimen figured, which seems to be referable to this genus although the allied genus Celtis suggested itself. A rather similar form from Florissant, Colorado, is doubtfully referred by Cockerell to the genus Morus.[1] The entire margin is a more constant character in Ficus than it is in either of these other genera and the venation is closer to that of the leaves usually referred to Ficus, which facts have largely determined the present identification.

Order ROSALES

Family *Platanaceae*

Genus Platanus Linné

PLATANUS ACEROIDES Goeppert?

*Platanus aceroides* Gœpp., Zeit. Deutsch. Geol. Gesell., 4:492. 1852.

Lesq., Am. Journ. Sci. (ii). 45:206. 1869.

Tert. Fl., 184. pl. 25. f. 4–6. 1878.

Proc. U. S. Natl. Mus., 11:19 pl. 5. f. 7. 1888.

Heer, Fl. Tert. Helv., 2:71. pl. 87. f. 1–11; pl. 88. f. 5–12, 15. 1856.

Fl. Foss. Arct., 1:111. pl. 12. f. 1–8; pl. 47. f. 3. 1868.

Knowlton, Bull. U. S. Geol. Surv. No. 204, 65. 1902.

Hollick, Md. Geol. Surv., Pli. & Pleist., 231. pl. 73; 74. 1906.

Two fragments of Platanus leaves showing neither the outline nor margin, but containing parts of two secondaries with the characteristic tertiary venation of this genus, were found at Richmond. Their specific affinity cannot be made out with certainty, and they are referred to this species with some hesitation. The tentative determination is made on the ground of the abundance of this species elsewhere at this time, and also immediately before and afterward. As far as the specimens will permit of comparison they agree perfectly with this form.

Family *Caesalpiniaceae*

Genus Podogonium Heer

PODOGONIUM? VIRGINIANUM sp. nov.

In the absence of the characteristic pods this generic reference can only be tentative. The species is based on a small rather thick leaflet,

[1] Cockerell, *Bull. Am. Mus. Nat. Hist.*, Vol. XXIV 1908, p. 88, pl. vii, fig. 19.

8 mm. in length by about 3 mm. in breadth, with a rounded-truncate apex and a somewhat narrowed acute base. Of the venation only the midrib is discernable.

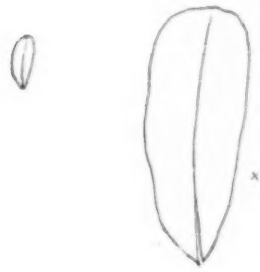


FIG. 6

The genus *Podogonium* is entirely extinct and is referred by Heer and others to the Caesalpiniaceae although Unger placed it in the Papilionaceae. In all there are about a dozen species, all Tertiary and ranging in age from the basal Eocene to the basal Pliocene (Messinian). It is chiefly European with but two species recorded from America. Five species have been found in the Tortonian of Europe.

Family *Papilionaceae*
Genus Dalbergia Linné f.
DALBERGIA CALVERTENSIS sp. nov.

FIG. 7

Leaflets small, 8 mm. long by 4.5 mm. in greatest width, which is toward the apex, obovate in outline with an emarginate to retuse apex and gradually narrowed acute base. Secondaries three pairs, opposite, ascending, camptodrome.

There are upward of eighty species of *Dalbergia* in the modern flora ranging through the tropics of both the old and the new worlds. The genus is abundantly represented during the Mid-Cretaceous by five or more species in Greenland and on the North American mainland. In Europe it is rather common during the Tertiary, Heer describing no less than four species from the Tortonian. There are also ten or a dozen species recorded from various European Oligocene localities.

Order SAPINDALES
Family *Celastraceae*
Genus Celastrus Linné
CELASTRUS BRUCKMANNI Al. Br.

FIG. 8

*Celastrus bruckmanni* Al. Br., in Stizenb. Verzeich., 87. 1851.
Heer, Fl. Tert. Helv., 3:69. pl. 171. f. 27–38. 1859.
Fl. Foss. Arct., 6. ab. 1:14. pl. 6. f. 5. 1880.
*Ibid.*, 7:130. pl. 84. f. 9. 1883.
Gaudin, Contrib., 6:22. pl. 3. f. 6. 1862.
*Rhamnus parvifolius* Web., Palaeont., 4:154. pl. 27. f. 16. 1855.

This nearly complete elliptical leaf closely resembles the leaves usually referred to this species, although suggestive of the leaflets of a number of species of the Papilionaceae. It is about 1.6 cm. long by 1.2 cm. in greatest width, with four or five pairs of camptodrome secondaries.

*Celastrus bruckmanni* was recorded originally from the Tortonian of Baden and has since been found at a number of European localities, some ranging as low as the Aquitanian. It is recorded by Heer (*loc. cit.*) from the Greenland Tertiary, but has not heretofore been found on the North American mainland.

Family *Anacardiaceae*
Genus Rhus Linné
RHUS MILLERI Hollick

FIG. 9

*Rhus milleri* Hollick, Md. Geol. Surv., Miocene, 485. f. lc, d. 1904.

This species which was described by Hollick a few years ago from the Calvert formation of the District of Columbia is represented by fragmentary specimens in the Richmond material.

In some respects these leaves suggest a relationship with *Myrica*, but the available material is so scanty that it is not desirable to make any change in the nomenclature. The missing parts in the figure have been restored from the more complete Maryland material, the outline of the Virginia specimen being indicated.

Order UMBELLALES
Family *Cornaceae*
Genus Nyssa Linné

FIG. 10

NYSSA GRACILIS sp. nov.

This species is based on a lanceolate, somewhat two-sided terete stone with about fifteen very narrow longitudinal ridges, possibly the remnants of slender wings. Length 8 mm., greatest diameter 2.5 mm., about equally pointed at both ends. The existing species of Nyssa number less than a dozen, inhabiting the warm temperate region of eastern North America and eastern and central Asia. A great many fossil species, founded chiefly upon stones, have been described, Perkins alone describing no less than eighteen species, an

altogether too large a number, from the Tertiary lignites of Brandon, Vermont. Leaves of two supposed species have been described from the Dakota Group and leaves and stones have been recorded from a large number of European localities, chiefly of Oligocene and Miocene ages.

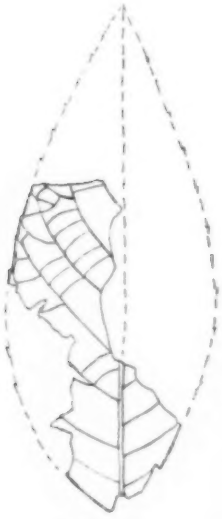

FIG. 11

Order GENTIANALES
Family *Oleaceae*
Genus Fraxinus Linné
FRAXINUS RICHMONDENSIS sp. nov.

Leaflets ovate in outline with a somewhat acuminate (?) apex and a rather rounded acute base, about 8 cm. long by 3.25 cm. in greatest width. Margin with very small remote serrate teeth. Secondaries ten or twelve pairs branching from the midrib at angles ranging from 65° for the basal pair to 40° for those in the apical part of the leaf, curving slightly upward, parallel, their tips joined by rounded festoons with the adjacent secondaries and sending off short curved branches to the marginal teeth. Balance of the tertiaries straight, transverse.

This species is based on the incomplete leaflet figured and its counterpart, and resembles both in size and outline the leaflets of the existing white (*Fraxinus americana* Linné) and red ash (*Fraxinus pennsylvanica* Marsh).

# EROSIONAL ORIGIN OF THE GREAT BASIN RANGES

CHARLES R. KEYES

It is not at all probable that the origin of the mountain ranges of the Great Basin of western America can find adequate and satisfactory explanation by a single simple hypothesis. Nor can it be advantageously postulated that the genesis of the mountains is the same in the various parts of that vaster desert region of which the Great Basin is only a minor portion. In general all recent observations go to show that these mountains as they exist today must be regarded as the outcome of the action of several sorts of geologic forces, operating sometimes severally and sometimes in conjunction, at diverse times and with different degrees of intensity.

The relative ascendency of the several geologic processes in shaping the larger relief features of the desert region has remained until recently an indeterminate quantity. It is this aspect of the subject that has been all but entirely overlooked. This neglect has led to very divergent opinions, as is shown by a full dozen of distinct hypotheses advanced to explain the origin of the Basin ranges.

In the consideration of the origin of the American desert mountains, it is usually assumed that they are strictly structural features. That they may have been fashioned, partly at least, by other means is a suggestion which is only beginning to attract the attention which it merits. Present indications are that erosion—eolian erosion—must be reckoned with as one of the potent factors in desert sculpturing.

Many descriptions of the Great Basin ranges have been published. Notwithstanding this fact there has not yet appeared, as Davis[1] well says, "any detailed statement of the theory by which they are explained; the essential consequences of the theory have not been explicitly formulated; the criteria by which a fault-block mountain may be recognized in early or later stages of dissection have not been defined."

[1] *Bull. Mus. Comp. Zoöl.*, XLII, p. 112, 1903.

Spurr[1] appears to be the first to bring into serious question the early explanation of Gilbert's, afterward adopted by King, Powell, Russell, and others,[2] regarding the simple fault-block origin of the Basin ranges. This author considers stream-corrasion as the most important or only sculpturing agency, but he expresses the opinion that erosion and upheaval have gone on together, more or less uninterruptedly ever since Jurassic times, the mountains being eroded from a folded substructure in the same way as in the case of the Appalachians, when the precipitation was much greater than at present, while "subsequently the climate became arid and the water-supply was not sufficient to remove the detritus from the valleys, which filled up." This view, however, as will be seen later, does not appear, according to Davis,[3] to be sufficiently supported.

The idea of the Basin ranges presented by Davis[4] recently is that they are "dissected fault-block mountains." The descriptions, and illustrations which accompany them, indicate clearly that the mountains are regarded as blocks first upheaved and tilted and then subjected to rapid corrasion by the mountain torrents, the intermont areas being deeply filled by the rock-waste of the contiguous highlands. This is practically Gilbert's hypothesis theoretically considered in its essential consequences, accompanied by the definition of some of the criteria by which the stages of dissection of a fault-block mountain may be recognized.

The Great Basin taken alone presents many difficulties to a clear interpretation of some of its most characteristic features. Farther south in the desert region, at the northern end of the Mexican tableland, there are displayed certain phenomena which seem to offer critical evidences bearing upon the question in hand. A few years ago I incidentally referred[5] to the probable significance of some of these features and to the physiographic evolution of that part of the country, regarding the region as a peneplain that had been uplifted in mid-Tertiary times, broken into high blocks, and then subjected to

[1] *Bull. Geol. Soc. America*, XII, p. 217, 1901.

[2] *Geog. and Geol. Expl. and Surv.* W. 100 Merid., Prog. Rept., p. 48, 1874.

[3] *Science*, N. S., XIV, p. 457, 1901.

[4] *Bull. Mus. Comp. Zoöl.*, XLII, p. 131, 1903.

[5] *American Geologist*, XXXIII, p. 22, 1904.

vigorous erosion, the effects of the latter being fully as important as the faulting in producing the present relief expression. Being fresh from the humid regions all denuding agents spelled water-action.

All of the above allusions to the erosional agencies in the desert ranges of the West have referred solely to the work of water. Of the possibility of the existence of any other effective denuding power there has been small hint. Only very recently have other erosive influences been suggested to account for some of the most conspicuous of the desert features. It now seems probable that wind-scour must be regarded as the chief erosive power in the dry regions.

In the Great Basin area the salient aspects of the country are quite different from the larger relief features of other parts of the western desert region. There is some of the faulting that is more recent and more profound than elsewhere. Late orogenic movements are perhaps more extensive. Evidences of much greater precipitation than now at no distant geologic date are manifest. No noteworthy streams traverse the district to disguise the effects of typical desert-leveling. Little is yet known in regard to the probable nature of the surface relief prior to the commencement of the present arid period. The general conditions are such as to present little critical evidence in support of any hypothesis yet proposed concerning the genesis of the desert ranges.

In other portions of the desert region far to the south and southeast of the Great Basin, in Arizona, New Mexico, and Old Mexico, there are many features suggestive of structures and conditions which formerly prevailed but of which there is small hint to be derived in the more northern area. The most noteworthy of these characteristics are the mesas, or plateau-plains, many of which now stand high above the present level of the intermont plains, or general plains-surface of the region. These mesas manifestly represent, as recently shown,[1] former positions of the general plains-surface. Their greater resistance to erosional influences and the general lowering of the region is due mainly to the protection afforded by extensive lava-flows which are now the capping-rock of the remnantal levels. The surfaces on which the lavas rest are true beveled rock-floors, just as in the cases of the present plains.

[1] *Bull. Geol. Soc. America*, XIX, p. 63, 1908.

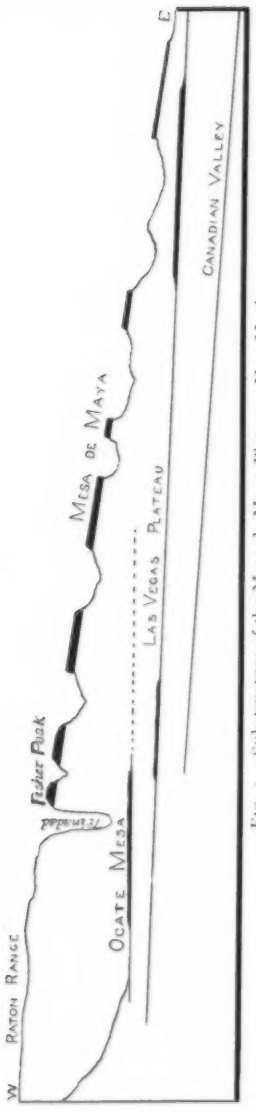


FIG. 1.—Substructure of the Mesa de Maya Plateau; New Mexico.

The most remarkable of these elevated plains is the Mesa de Maya, in northeastern New Mexico. Its extension is the flat crest of the Raton Range. The greater part of the mesa is formed by a thick basalt plate, 500 feet in thickness, resting on the beveled edges of soft Laramie shales and sandstones. This mesa is gently inclined to the eastward and extends from the Rocky Mountains a distance of more than one hundred miles to beyond the Texas line. (See fig. 1). It is 3,500 feet above the next extensive plains-level below, known as the Ocate mesa, which in turn is 500 feet above the general plains-surface of the region, or the Las Vegas plateau. It appears that the Mesa de Maya represents practically a Tertiary peneplain which existed at the time of the general elevation of the region. At the town of Raton its surface is now 9,000 feet above tidewater. Were it not for the great lava-field the remnants of which constitute this plateau-plain there would today remain no undoubted traces of the old peneplain in this part of the country.[1]

That the Mesa de Maya is the remnant of what is essentially a peneplanation-level which, perhaps, once extended over much, if not most, of the present desert region around the southern end of the Rocky cordillera, is strongly supported by a number of facts: (1) The foundation strata, both hard

[1] *Proc. Iowa Acad. Sci.*, XV, p. 221, 1908.

and soft, which alternate frequently, are evenly beveled, indicating that the country at the time of planation must have been only slightly above the sea-level. (2) The principal orogenic deformation and faulting appears to have taken place in early or mid-Tertiary times, and prior to the period of the general planning-off of the country, as represented by the Mesa de Maya level. (3) The numerous mountain ranges of New Mexico, outside of the Rockies, are subequal in height, a fact, when taking into account the period of the principal deformation and faulting, the general alternation of hard and soft belts of rock, and the extent of the subsequent denudation, showing that the present cycle of erosion must have started with the country already more or less of a plain. (4) The present bilateral symmetry of most of the desert ranges, even in the cases of the so-called tilled block-mountains, as the Jemez, Sandia, Franklin, Magdalena, and Caballos ranges, for examples, is suggestive of long-continued attack by the elements upon the hard mountain rock. In each of the mountains mentioned the major fault-line, if it really exists, is as far from the crest of the mountain-ridge as is the foot of the backslope. (5) Plateau plains that lie high above the present general plains-surface, but still far below the Mesa de Maya level, are beveled rock-surfaces, protected usually by lava flows. (6) With all of the present ranges of the so-called block-type bordered on either side by soft beds of great thickness, and the very resistant mountain strata, in monoclinal attitude, once extending such relatively long distances beyond the present mountain crests, it does not seem likely that general lowering of the surface of the country could have gone on so evenly without something of a plains-surface to begin with. (7) The postulation of a general mountainous surface at the commencement of the present geographic cycle as represented by the Mesa de Maya planation surface finds many incongruities which need not be dwelled upon at this time.

How utterly inadequate is any purely tectonic explanation of the larger relief features of the Western desert region, as they today exist, becomes readily apparent so soon as the real nature and the physiographic significance of certain of these characteristics are taken into account. In the consideration of erosional effects in the desert there are some important pecularities which are commonly overlooked.

The principles of water-action in the normal humid lands are applied with the only reservation that there is somewhat less water involved. No distinction is made between the efficiency of water-action on the plain and in the mountain. On the plains, with the exception of the local and sporadic flood-sheet, the general effect of water as a corrading agent is practically *nil*. A very large part of what rainfall occurs on the plains sinks at once into the ground. On the mountains where the general erosion effects have been chiefly observed the results are not so very unlike what they are in the humid regions generally.

By all those who, with the idea of genesis in mind, have recently traversed the region, it is conceded that erosion has had much to do with giving to the desert country its present topographic expression. That the erosion is not chiefly water-erosion but mainly eolian in character is an aspect of the subject which has received but scant attention. The potency of wind-scour as an erosive agent under conditions of dry climate is amply shown in many ways, and to an extent heretofore unsuspected. Its grander effects as compared with those of water corrasion are quite distinctive. Among them none is more characteristic than the beveled rock-floor which the intermont plains of the arid region present, as fully described in detail in another place.[1] Its real significance as indicating that these plains are areas of marked degradation instead of aggredation, as commonly supposed, is here especially pointed out. The vastness and evenness of the intermont plains have no known counterpart among the plains of the humid regions. Desert plains are smoother than peneplains possibly can be, as Passarge has stated. The singular isolation of the desert ranges, for they are usually completely encompassed by plains as by the sea, the entire absence of foothills, the plains-character of the rock-floor itself,[2] the representation of former plains-levels by the plateau-plains, the remarkable thinness of the surface mantle of débris, the total absence of distinct water-ways on the plains,[3] the notable independence of, and marked differences in, level of contiguous plains, and the general tectonic characters,[4] are inex-

[1] *Am. Jour. Sci.* (4), XV, p. 207, 1903; also *Bull. Geol. Soc. America*, XIX, p. 86, 1908.

[2] *Eng. and Min. Jour.*, LXVIII, p. 670, 1904.

[3] *American Geologist*, XXXIV, p. 160, 1904.

[4] *U. S. Geol. Sur.*, Water Sup. Pap. No. 123, 1905.

plicable by any method of water-sculpturing. They are all readily accounted for, however, through eolian activities under conditions of an arid climate.

The close tectonic pattern of the American desert region has done much to obscure the real significance of its most striking features. In South Africa, where the great elevated plateau of the dry region has been long relatively free from orogenic movement, there are the same isolated mountains, the same vast and even intermont plains, and the same streamless country. In that region the vigor of wind-scour action and the impotency of water corrasion is amply attested by the recent observations of Passarge,[1] and others. In the Great Basin the wind as a factor in general erosion appears not less effective. It seems probable that we must now regard wind-scour not only the most important erosive agent under conditions of aridity but more potent than all other agencies combined. Moreover, in the production of the present desert mountains its influence doubtless very far surpasses that of any recent deformation or dislocation.

From a view-point of true desert conditions all late observations in the arid country of southwestern United States go to show: (1) That there existed at the beginning of the present geographic cycle a broad peneplain at a level of about 4,000 feet above the present plains-surface; (2) that the major faulting and gentle folding of the region took place chiefly before the beginning of the present cycle; (3) that water-action is unimportant; (4) that wind-scour is very potent; (5) that the belts of hard and soft strata produced by the deformation in former cyles allowed the winds to erode the latter much more rapidly than the former, producing the present plains, and leaving many of the former as monadnock ranges; and (6) that while differential movements of the rock-masses have in all likelihood taken place recently and locally their direct effects compared with those of eolian erosion have been relatively unimportant in the formation of the present orographic expression of the desert country; and (7) that, all things considered, the comparative values of deflation and corrasion in the arid regions may be expressed by the estimate that the volume of rock-waste brought down by the waters from the mountains in a year may be removed by the winds in a single day.

[1] *Zeitsch. d. deutschen geol. Gesellschaft*, LVI Bd., Protokol, pp. 193–209, 1904.

# A CONTRIBUTION TO A MONOGRAPH OF THE EXTINCT AMPHIBIA OF NORTH AMERICA. NEW FORMS FROM THE CARBONIFEROUS

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In the course of an extended investigation of the extinct Amphibia of North America the writer has studied several forms from the Carboniferous which cannot be referred to any known species and they are here described as new. He has, so far, studied thirty-five species of the Carboniferous Amphibia of North America, all of which, with one or two exceptions, belong to the Branchiosauria and Microsauria. The Branchiosauria are represented by a single species. Of the Microsauria there has been an abundance of material available, thanks to the kind offices of Dr. Bashford Dean and Dr. Louis Hussakof of the American Museum, who very generously gave the writer the privilege of examining nearly a hundred of the specimens studied by Cope. There are already prepared some two hundred pages of manuscript and nearly sixty drawings toward the completion of a monograph of the extinct Amphibia of North America, but as the publication of this must be deferred until the remainder of the known North American and the European species have been studied, it is thought advisable to describe the following forms in advance, the more detailed treatment of the described forms being held for the monograph.

The extinct Amphibia of the North American Paleozoic present a variety of forms, of very diverse organization. The forms known range from very small creatures like *Micrerpeton caudatum*, less than two inches in length, to large forms like *Eryops megacephalus* Cope from the Permian of Texas, which probably attained a length of eight or ten feet. A rather interesting parallel can be drawn between the Paleozoic Amphibia and the reptiles of today. The snakes are represented in the Paleozoic by the limbless, snake-like Amphibia, such as *Ptyonius*, *Dolichosoma*, *Ophiderpeton* and *Molgophis* of North

America and Europe. The lizards find their counterpart in the Hylonomidae and the Tuditanidae. The turtles are represented by *Dissorophus* and its allies from the Texas Permian and the crocodilian aspect of the fauna is found in the large labyrinthodonts of the Permian, but more especially of the Triassic.

The Amphibia whose remains are found preserved in the Carboniferous rocks of North America all belong to the order Stegocephala, characterized by the completely roofed-over cranium and the great development of the parasphenoid. Five suborders of the Stegocephala may be recognized. These are: The Branchiosauria, The Microsauria, The Aistopoda, The Temnospondyli, and The Stereospondyli. All five of these suborders are represented in the Carboniferous of North America but it is our purpose here to examine only forms belonging to the first two suborders, i.e., the Branchiosauria and the Microsauria.

The Branchiosauria were salamander-like in form and were, for the most part, devoid of the heavy dermal armor of many of their contemporaries. They were naked, with the exception of small ovoid scales on the back and the chevron-shaped armature of the ventral surface which was almost universally present among the Carboniferous Stegocephala and may have been present in the Amphibia as late as the Laramie Cretaceous. The tail was rather long and flattened from side to side and the creatures were adapted for life in the water for at least the early part of their existence, as is shown by the possession of gills in many of the Permian and late Carboniferous forms of Europe. The group of the Branchiosauria are without doubt the direct ancestors of the modern salamanders and perhaps of the other groups as well. No branchiosaurian has ever been described from so low in the geological series as the one here given and it is the first evidence of the occurrence in North America of a group which was so abundant in Europe during the Permian.

### Micrerpeton caudatum gen. et sp. nov.

(Figs. 1–7)

The genus *Micrerpeton*, of which the single species is described below, is the only evidence of the occurrence of the Branchiosauria in North America, and as such is of unusual interest. There have

been three other genera referred to the Branchiosauria from the North American deposits but there is good evidence that none of them belongs here. The genus *Amphibamus* (Fig. 24) was originally referred to the Xenorhachia by Cope[1] on account of the supposed cartilaginous condition of the vertebrae and the absence of ribs. Later he abandoned this order and placed the form in the order Branchiosauria where it is retained by Zittel.[2] Recently Hay[3] has shown, and I am able to corroborate his statement, that there are ribs present in the species *Amphibamus grandiceps* Cope, and that they are long and curved, not at all like the short ribs of the true Branchiosauria. These long, curved ribs unquestionably exclude the form from the Branchiosauria and indicate its close affinites with the Microsauria. The genus *Pelion* has also been referred to this group on purely negative evidence.[4] The genus is excluded from the Branchiosauria by the well-ossified condition of the limb bones, in which the endochondral ossification is seen to be well-developed, a condition which never prevailed among the Branchiosauria so far as is known. The form of the head and the elongated hind limb would also tend to exclude this form from the group. In the Branchiosauria the fore limb is usually larger than the hind limb, but in *Pelion lyelli* Wyman the hind limb greatly exceeds the fore limb in length. The genus *Sparadus* as it occurs in North America has also been referred to this group by Lambe.[5] In the first place the presence of the genus *Sparodus* in the deposits of North America is so uncertain as to render consideration of the form almost unnecessary. The presence of the genus is indicated by remains which are almost impossible of definition and such a reference as made by Dawson is at the best an uncertain one.

The form, *Micrerpeton caudatum*, is represented by very complete remains (Pal. Coll., U. of C., No. 12,313). The specimen is preserved on opposite halves of a nodule from the Mazon Creek beds of Grundy County, Illinois. In a recent conference with Dr. David White

[1] *Proc. Acad. Natl. Sci. Phila.*, 1865, pp. 134–37.

[2] Zittel, *Handbuch der Paleon.*, 1 Abth., Bd. 3, p. 375.

[3] *Proc. Amer. Phil. Soc.*, 1900, p. 120.

[4] Zittel, *Handbuch der Paleon.*, 1 Abth., Bd. 3, p. 375.

[5] *Trans. Roy. Soc. Canada*, 1904–5, Vol. X, p. 45.

he stated that the Mazon Creek beds are possibly to be placed somewhat lower than the Lower Kitanning, so that the deposits are in the lower part of the Allegheny series as they are now understood. The specimen was collected many years ago by Mr. W. F. E. Gurley at Mazon Creek but it has never been studied, although Dr. Newberry examined it and pronounced it to be amphibian and said in a note that Professor Cope should see it. Unfortunately Cope did not see it and it has lain unknown in the collection as unnoticed by students as if it were still in its old bed. I am indebted to Dr. Stuart Weller for calling my attention to the specimen and to him is due the interest which I have taken in the form.

The specimen (Fig. 1) is exceptionally perfect. Not only are nearly all of the skeletal elements present but the general contour of the body, the character of the dermal covering, the color-markings, the lateral line system, and many other features of interest have been detected. Such completeness of preservation is very uncommon even among the remains obtained from this locality. In this case the entire form was preserved but the collector in cracking the nodule lost the chips containing the hands and feet so that portions only of the limbs remain. It is thus impossible to determine the phalangeal formula, but the feet were probably like those of *Branchiosaurus amblystomus* Cred., as given by Credner, to which the present form is closely allied and indeed must be placed in the same family with *Branchiosaurus*, *Pelosaurus*, and *Melanerpeton*.

The remains here described represent a small salamander-like form, and they are the earliest geological evidence of the group, which without doubt gave rise to the modern salamanders. The parts preserved in the specimen are: the complete outline of the head with the cranial elements easily distinguishable and the black pigment of the iris; the entire vertebral column including pits in the tail region where the vertebrae were without doubt entirely cartilaginous; parts of the pectoral girdle; parts of the pelvic girdle; the humerus of the left side; the ventral scutellation; the ribs of one side of the body; and indications of ribs on the other; portions of both hind limbs and a complete impression of the fleshy tail. On this impression of the tail are preserved small horny scales, transverse color-markings, and distinct impressions of the lateral line system.

The bones of *Micrerpeton*, as in so many of the fossils from this locality, have been replaced by a white friable mineral which is

FIG. 1

FIG. 2

FIG. 1.—Impression of *Micrerpeton caudatum* on the Mazon Creek nodule. The median lateral line is distinct and evidences of the ventral scutellation may be seen on the upper side of the vertebral column. Two and one-third times natural size.

FIG. 2.—A photograph of the ventral scutellation of *Micrerpeton*. ×5.

probably kaolin. The animal is preserved on its back and the photograph (Fig. 1) represents the ventral surface of the form. The entire length of the animal is only 49 mm of which the tail occupies nearly one-half.

The head has much the same shape as in the species of *Branchiosaurus*, figured by Fritsch and Credner. The eyes occupy relatively the same position as in that genus. The orbits are very large and are broadly oval. Within the borders of the rim the stone is blackened as though by the black pigment of the iris such as Cope has described in *Amphibamus*.[1] Under a rather high power of magnification the cranial bones are seen to be represented by mere flakes of white mineral matter. The sutures separating the cranial elements are distinctly preserved on the obverse of the main nodule and the description of the elements will be as they are there depicted.

The openings of the skull are five: the two orbits, the two minute nostrils and the pineal foramen. A median suture separates the skull into two equal halves and the pineal foramen lies slightly anterior to the posterior third of its length. The boundaries of the premaxillae are not distinct but they were very small elements and formed the inner border of the nostrils which are clearly indicated by bosses of stone. The nasal element is nearly square and lies anterior to the frontal which it borders broadly. The parietal is about the same size as the frontal and it apparently forms a portion of the inner border of the orbit although this is not an assured character. The parietal is elongate and unites posteriorly with the supraoccipital. The supraoccipital with the epiotic and the supratemporal (prosquamosal) form the posterior boundary of the skull and they are hence not unlike the same elements in other Stegocephala. The prefrontal forms the anterior border of the orbit. The lachrymal has not been detected. The maxilla is elongate and forms the antero-lateral border of the skull. No teeth nor impressions of teeth have been detected. The maxilla is elongate and forms the antero-lateral border of the cranium. The jugal forms an important element in the lateral border of the cranium and joins the quadratojugal posteriorly. The postfrontal is triangular and with the postorbital forms the posterior border of the orbit. Both of the elements are acuminate posteriorly although the

[1] *Proc. Acad. Natl. Sci. Phil.* 1865. p. 137.

suture between them is indistinct. They inclose between their posterior acuminations an interior projection of the squamosal. The squamosal has the usual relations and borders the supratemporal laterally. The latter element forms the quadrate angle of the cranium.

The entire length of the vertebral column is preserved although the nature and structure of its elements cannot be determined. The impressions of a few of the vertebrae show that some of the centra were amphicoelous but other than this nothing can be stated. The cavities which the centra occupied were filled by the white mineral matter and the force of the blow which cracked the nodule destroyed the form of the mold. It is possible that where the mineral matter has filled the cavities the centra were bony or partly so and where the cavities were unfilled the centra were entirely cartilaginous. The length of the vertebral column from the base of the skull to the last impression of a cartilaginous centrum is 33 mm.

The number of centra between the sacral vertebra and the skull is twenty (Fig. 5) as they are preserved but there may have been one more, the atlas. Fritsch has represented twenty-one in his restoration of *Branchiosaurus salamandroides* and this is further indication of an affinity between the two genera although Credner has represented twenty-six presacral vertebrae in *Branchiosaurus amblystomus*. The presacral vertebrae are thus seen to vary within narrow limits, but the number of presacrals is near twenty and this may be taken as typical. It is interesting to notice that in modern forms of the salamanders the presacral vertebrae are about twenty. The significance of this will be discussed elsewhere. There is but a single sacral centrum in *Micrerpeton*. The sacral rib has not been detected but it is restored after the condition given in *Branchiosaurus*. The right femur partially covers the sacral vertebra. Its structure cannot be determined. I count impressions of seventeen caudal centra of which at least twelve may have been partially ossified. In the cervical region there are distinct impressions of transverse processes on at least five vertebrae and this number is assigned to the neck although it is by no means certain that this is the correct number. The neck was at least short if we may judge from the position of the remains of the pectoral girdle. No cervical ribs are definitely determined. There is a short

rib lying between the fifth and sixth vertebrae but to which it belongs is uncertain.

There are impressions of ten ribs preserved on one side of the vertebral column and one on the other side. They are short, straight, and heavy as are the same elements in *Branchiosaurus*. This character alone is sufficient to place *Micrerpeton* among the Branchiosauria since no such ribs are known in other groups of the Stegocephala. The ribs preserved lie next the seventh to the seventeenth vertebrae on the left side and there is one on the right side which may belong to either the fifth or sixth vertebra. The ribs are central in their attachment and in this they agree well with the mode of rib attachment of the ribs in modern salamanders. All of the ribs are single headed and are composed, for the most part, of perichondral tissue. The position of the ribs in the matrix, inclined backwards and making a small angle with the vertebral column is very suggestive of the condition found in *Branchiosaurus*.

The pectoral girdle is represented by three distinct elements of the left side. They are identified as scapula, clavicle, and coracoid. This is the nomenclature given by Woodward although Credner would call them otherwise. The nomenclature and morphology of the elements of the pectoral girdle will be discussed fully elsewhere and is not necessary here. The scapula is represented by an ovoid fragment lying next to the vertebral column. The clavicle was probably spatulate as it is in *Melanerpeton* but the inner end of the element is not visible. The coracoid is represented by its outer end only and its inner pointed extremity is not visible. The interclavicle has not been detected.

The humerus lies somewhat to one side of the pectoral girdle as if there had been a large amount of articular cartilage. Its position may be due to post-mortem shifting but there is little other evidence of any movement after deposition. The humerus is a large heavy bone in comparison to the rest of the skeleton. It is expanded at each end and its ends show concavities proving that the bone is formed principally of perichondral tissue as would be expected from such an early Branchiosaurian. The endochondrium has not yet developed in this form which is evidently adult. There is no other element of the arm present.

Of the pelvis there is but a single element present. This is a slender elongate rod and it is undoubtedly the ilium since it has the usual position for that element and is much too large for a sacral rib. It has much the same shape as in the modern *Salamandra*. It is not expanded as in the ilium of *Branchiosaurus*. This element, like the humerus, seems to have been but a hollow cylinder of bone and undoubtedly had cartilaginous ends as in the ilium of the recent *Salamandra*.

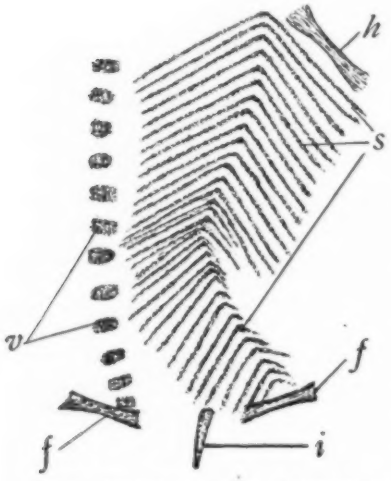


FIG. 3.—Ventral scutellation of *Micrerpeton caudatum*. F = femur; H = humerus; I = ilium; S = the lines of scutes; V = the vertebral column. ×5.

The two femora are preserved nearly entire. The right one lies upon and partly obscures the sacral vertebra. The femur is much more slender than is the humerus. It is but slightly expanded at the ends and like the humerus shows the concavities at the ends indicative of the perichondral character of the tissue composing it. The endochondral tissue is a later development and finds its first expression late in the embryonic and phylogenetic development of the vertebrates. Of the leg there are two elements preserved more or less entire (Fig. 5). These are the tibia and the fibula. The larger one may represent the tibia and the smaller one the fibula. They both present characters similar to those of the femur and the humerus. They are both rods of bone tapering at the distal end. The feet have been lost, though doubtless at one time present.

The ventral surface of the body, as in other members of the Branchiosauria, was covered and protected by a series of small scutes arranged in the regular chevron pattern (Figs. 2, 3). The form of the scutes and their number cannot be determined. The

lines which represent them are, however, distinct. A portion of the scutes are missing and part of them are obscured by lying over the vertebral column. They are all somewhat shifted to the left. The lines are very small and close together. I count sixteen of them in a distance of two millimeters. In length the longest line preserved is a little more than four millimeters, measuring from the point of the chevron. The lines representing the scutes came to a point in a median ridge which is now represented by a line. The dermal scutes on the abdomen were probably the forerunners of the abdominal ribs of the reptiles.

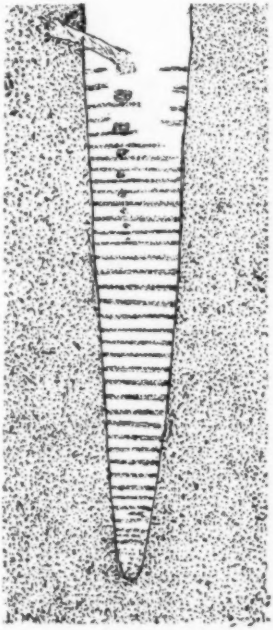

FIG. 4.—The banded color-markings on the tail of *Micrerpeton*. ×5.

The impression of the tail contains some of the most interesting features in the entire specimen. Scattered over it and in places laid in a mosaic are impressions of small dermal scales which may have covered the entire body. In form the scales are ovoid, being half as wide as long (Fig. 6). The markings on the scales partake of the nature of radiating lines much after the pattern of the sculpturing of the cranial bones in many of the Microsaurial and later forms. The scales are less than one-half a millimeter in diameter and their character can only be ascertained under high magnification. Near the middle part of the tail there are preserved distinct transverse bands of a dark color (Fig. 4). These markings are more or less evident throughout the entire tail impression but they are elsewhere not so distinct as in the central region. The lines are evidently due to rows of pigmented scales and in all probability the animal's entire body was transversely striped.

The most interesting and important single structure discovered on

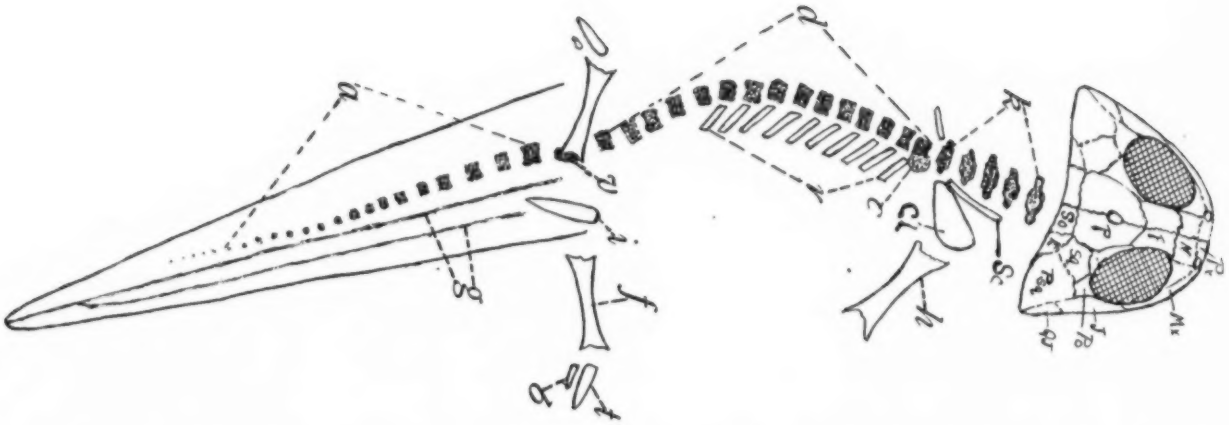

FIG. 5.—The skeletal elements of *Micrerpeton caudatum*, as preserved. E = epiotic; F = frontal; J = jugal; M = maxilla; N = nasal; P = parietal; Po = postorbital; Px = premaxilla; Qj = quadratojugal; Psq = supratemporal; So = supraoccipital; a = caudal vertebrae; b = fibula; sc = scapula; d = dorsal vertebrae; f = fibula; g = lateral line; h = humerus; i = ilium; k = cervical vertebrae; r = ribs; t = tibia; cl = clavicle; v = sacral vertebra; c = coracoid (?). ×5.

the specimen is the impression of the lateral line system, which is clearly evident as two dark lines on the impression of the fleshy part of the tail. The sense organs are represented by two longitudinal rows of pigmented scales, one beginning at the tip of the tail, the other

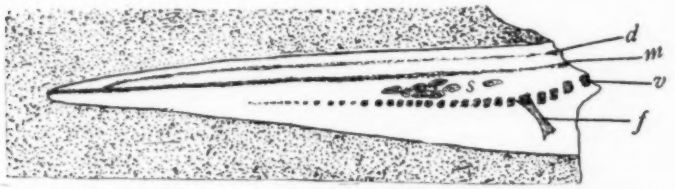


FIG. 6.—Impression of the tail of *Micrerpeton caudatum* showing the arrangement of the lateral line sense organs and the position of the vertebral column. D = dorsal lateral line; M = median lateral line; F = femur; S = scales; V = vertebral column. ×5.

taking its origin from the median line somewhat further forward. I am indebted to Dr. K. Takahashi for calling my attention to the similarity of this arrangement to that found in the modern *Necturus*. The arrangement and disposition of the lines containing the sense

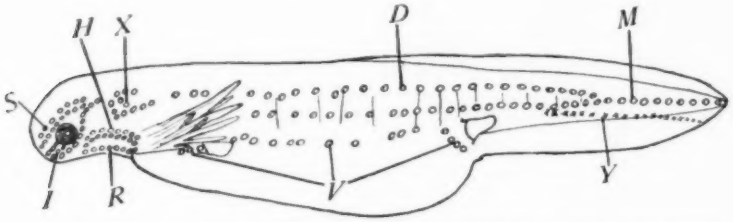


FIG. 7.—Outline of a young larva of *Necturus* showing the position of the lateral line system. D = dorsal lateral line; H = hyomandibular sense organs; I = infraorbital sense organs; M = median lateral line; R = mandibular sense organs; V = ventral lateral line; X = sense organs supplied by branches from the glossopharyngeal and vagus nerves; Y = the position of the vertebral column. Modified after Platt. Enlarged.

organs is practically the same in the two forms (Figs. 6, 7). The median lateral line takes its origin from the extreme tip of the tail and is continued to the base where the impression is broken. The dorsal lateral line has its origin rather abruptly from the median lateral line at a distance of six millimeters from the tip of the tail. The

sense organs were undoubtedly located beneath specialized pigmented scales on the surface of the animal's body and to this pigment is due the preservation of the lines.

The fact that the arrangement of the sense organs of *Micrerpeton* corresponds so exactly to the condition found in *Necturus* is of considerable interest. *Necturus* alone among the modern tailed Amphibia has the arrangement above described for the lateral line system in *Micrerpeton*. All other forms of the Caudata as also the larval forms of the Salientia have an arrangement of the lateral line system which is perfectly distinct from that found in *Necturus*, although the basal arrangement is the same in nearly all forms. In *Ambystoma*, for instance, the median lateral line is not present on the tail and the dorsal line is but incompletely developed. The close similarity of the arrangement of the systems of sense organs in the two forms, *Micrerpeton* and *Necturus*, may be of genetic significance with regard to the latter form. The lateral line sense organs are of a very fundamental significance and it is not at all improbable that the same arrangement of the lines has existed from the Carboniferous times down to the present. We know that such has been the case in a great many of the fishes. The ancestors of the modern Caudata must have originated somewhere in the Carboniferous or earlier periods and it is the opinion of the writer that the Branchiosauria represent the direct ancestral forms for this group of the modern Amphibia. This suggestion is by no means new, since Baur and others have held the same view. The writer hopes to present a fuller discussion of this topic at some future time.

The relations of the form *Micrerpeton caudatum* are readily determined. The number of the presacral vertebrae, the form and position of the ribs, the shape of the skull, the arrangement of the cranial elements, the structure of the pectoral girdle, and the character of the ventral armature all clearly bespeak a close relationship with *Branchiosaurus*, *Melanerpeton*, and *Pelosaurus* from the Lower Permian and Upper Carboniferous of Europe. The distinction of the genus *Micrerpeton* from the other known branchiosaurian genera is found in the apparent absence of sclerotic plates, the shape of the skull, the arrangement of the cranial elements and the form of the ilium.

So far as I am aware the species above described is the earliest geological evidence of the Branchiosauria since the earliest forms known from Europe are from the Stephanian (Upper Carboniferous). The species is also the only true branchiosaurian known from North America as stated above. The presence of this form in America is of considerable interest in the bearing it has on the distribution and migration of the Paleozoic animals. It is a great distance from Europe where the other Branchiosauria are found, to America and it must have taken an immense length of time for such slow-moving creatures as the Amphibia to have migrated this distance. Whether the migration took place after the development of the branchiosaurian type or whether the type was evolved in the two places is an open question and must be settled by future research. It is possible that it was the piscian ancestors of the Amphibia which migrated across the seas and began the amphibian phase of their development independently in the two continents.

MEASUREMENTS OF THE SPECIMEN OF *Micrerpeton caudatum* MOODIE

| | mm |
|---|---|
| Entire length of animal | 49 |
| Length of head in median line | 6.5 |
| Width of head at posterior border | 8 |
| Length of orbit | 2.5 |
| Width of orbit | 2 |
| Interorbital space | 2 |
| Length of vertebral column | 33 |
| Length of single vertebra in dorsal series | 0.5 |
| Length of trunk from base of skull to sacrum | 22 |
| Length of rib | 1.5 |
| Length of scapula | 3 |
| Width of clavicle, maximum | 2 |
| Length of humerus | 2.5 |
| Length of ilium | 1.5 |
| Length of femur | 2 |
| Length of tibia | 1.5 |
| Length of tail impression | 21.5 |
| Width of tail impression at base | 4 |

The Microsauria are represented in the Carboniferous of North America by numerous forms usually with well-developed dermal plates and almost always with the ventral scutellation. They ranged

in size from the small *Tuditanus minimus* from the Cannelton slates of Pennsylvania, three or four inches in length, to forms like *Diplocaulus* and possibly *Macrerpeton* which without much doubt reached a length of several feet. All the members of this suborder had well-developed cranial elements which are usually ornamented with radiating grooves or with pits. The pectoral arch is well developed and is composed of dermal elements which are ornamented with sculpturing similar to that of the cranial bones. The body of these animals was in a few cases covered with overlapping scales, but others appear to have had only the ventral surface armed and this was in some cases especially strong as in the genera *Saurerpeton* and *Sauropleura*. The vertebrae are uniformly of the phyllospondylous type. This is so generally the case that the condition of the vertebrae is taken as one of the chief characters of the group. Various peculiarities are seen among the Microsauria in the development of horn-like projections on the skull in genera which are in no way genetically related. The Microsauria continued on into the Permian in the family Diplocaulidae.

The genus *Tuditanus* is represented by several species in the Carboniferous rocks of North America. Eight species are associated provisionally under this genus. Six of them were described by Cope from the Linton deposits of Ohio and two are described herewith from the Cannelton slates of Pennsylvania. A discussion of only three of the species will be given here since little of interest has been obtained from the study of the other species. The three forms here discussed are *Tuditanus tabulatus* Cope, *T. minimus* sp. nov., and *T. sculptilis* sp. nov. The facts which make the first-named species of interest here are the discovery of the lateral line canals on the skull and the correction of several errors in the original description as given by Cope.

### TUDITANUS TABULATUS Cope.

(Figs. 8, 9)

The species is known from a single well-preserved skull and its obverse in the collection of the Columbia University of New York City. I am indebted to Dr. Bashford Dean for the privilege of studying this interesting form. It is from the Linton deposits of Ohio.

The remains include a nearly complete cranium and a complete clavicle of the right side. The species agrees in all essential respects with the characters of the genus *Tuditanus*, presenting a broad, flat head, and a triangular thoracic shield.

The cranium is wider than long and the muzzle is broadly rounded (Fig. 8). The orbits are wide ovals, and their posterior borders fall little behind the transverse line dividing the skull equally. The interorbital width equals the longitudinal diameter of the orbit. The posterior outline of the cranium is truncate in a straight transverse line between the prominent epiotic angles. The composition of the cranium is different from any of the other species referred to this genus in the large size of the epiotic and the fact that the squamosal is excluded from the parietal by the extension of the postorbitals and the epiotics. This may be a generic character and entitle the form to another name but it is retained here for the present. The elements of the anterior part of the skull are not preserved but they are indicated by the broken lines. The nostrils are, however, clearly indicated as bosses of shale. There is a mere fragment of the nasal preserved posterior to the crack indicated by the transverse line (Fig. 9). The frontal is elongate as in other species of the genus and forms the inner border of the orbit. The parietal, as usual, is one of the larger bones of the skull roof and the pineal foramen is inclosed in the median suture by the two parietal elements. The parietal opening lies in

FIG. 8.—The skull and right clavicle of *Tuditanus tabulatus* Cope. One and one-half times natural size.

the posterior half of the parietal. The supraoccipital is almost square being slightly elongate transversely. It unites laterally with the epiotics with which it forms the truncate table of the skull. The suture separating the epiotic from the squamosal is clearly distinct. Although such a position for the squamosal is unusual it is not unique since the same character has been observed in *Diceratosaurus laevis* to be described later. The postfrontal is rather small and it together with the postorbital forms the posterior boundary of the orbit. The postorbital is truncate posteriorly and joins the epiotic broadly. The squamosal lies posterior to the postorbital and jugal and borders the quadratojugal which is an unusual condition but what significance the condition has remains to be determined. Posterior to the squamosal lies the supratemporal which forms the quadrate angle of the cranium. The quadratojugal is a small element and forms a part of the lateral boundary of the skull. The jugal is a large element and forms the entire lateral border of the orbit. There are no teeth preserved on the fragment of a maxilla but there are some impressions farther forward which resemble the pleurodont denticles of the modern Amphibia.

The sculpture of the surface of the cranium consists of parallel ridges which are separated by grooves equal to them in width. The ridges radiate inward on the squamosals and frontals and outward on the supratemporals. They are somewhat interrupted on the other skull elements. The lateral thoracic shield, which represents the right clavicle, is ornamented with a similar sculpturing of uninterrupted radiating ridges. Cope described an atlas in connection with this skull but I do not find it. The slender impressions to the right of the pectoral shield may possibly represent ribs. They are gently curved and truncate at the inner end.

A nearly complete system of lateral line canals has been detected on this skull (Fig. 9). The canals preserved are: the temporal, the jugal, the infraorbital, the occipital cross-commissure and the supraorbital. The nomenclature of the canals is that adopted in a contribution on the sensory canals in the extinct Amphibia now in press. The occipital cross-commissure is represented by a row of elongate pits such as Andrews[1] has described for *Ceraterpeton galvani* Huxley

[1] *Geol. Mag.*, Dec. IV, Vol. II, p. 81.

from the Coal-measures of England. The cross-commissure is contained within the epiotics. The jugal and the temporal canals form a complete ring much as the same canals do in *Trematosaurus*. The squamosal in *T. tabulatus* is excluded from the parietal by the extension of the epiotic and the postorbital and it is to be noticed that the temporal canal has a changed position to correspond with the changed condition of the squamosal. This is of considerable interest in connection with the correlation of the squamosal in fishes and amphibians. This subject has been fully treated in another place, and it will only be necessary here to state that on the basis of the lateral line canals and their arrangement in the fishes and the Amphibia the true correlation of the squamosal element in amphibians and fishes has been made. This contradicts the results obtained by Thyng[1] from embryological studies. Thyng's results are noticed more fully in the paper above cited. The temporal canal has apparently an indication of a connection with the supraorbital canal but of this I am not sure. The jugal canal occurs on the supratemporal, quadratojugal, and it joins the infraorbital on the jugal. The infraorbital is indicated by a short portion some few millimeters long under the orbit and the rest, i.e., its connection with the jugal canal, is restored. There is nothing unusual to be observed in that portion of the infraorbital canal which is preserved. The supraorbital canal is indicated by a curved, broad, shallow groove on the inner side of each orbit. As above stated there seems to be a connection between this canal and the temporal but I am not sure. The primitive conditions shown in the lateral line canals in *T. tabulatus* are the presence of the occi-

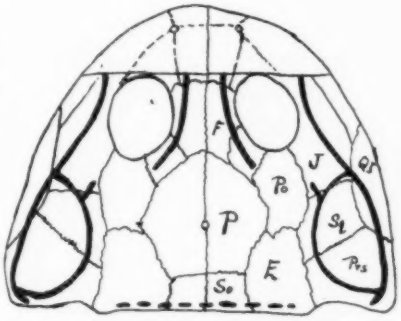


FIG. 9.—The outline of the cranial elements and the lateral line canals in *Tuditanus tabulatus* Cope. One and one-half times natural size.

[1] "*Tufts College Studies*," 1906, Vol. II, No. 2.

pital cross-commissure and the ring-like formation of the temporal and jugal canals which is too clearly indicated to be overlooked.

MEASUREMENTS OF THE TYPE OF *Tuditanus tabulatus* COPE

| | mm |
|---|---|
| Median length of the skull | 29 |
| Width of skull at posterior border, estimated | 37 |
| Width between epiotic angles | 18 |
| Length of orbit | 8 |
| Width of orbit | 6.5 |
| Diameter of nostril less than | 1 |
| Diameter of pineal foramen less than | 1 |
| Length of right clavicle | 13 |
| Width of right clavicle | 5.5 |

The specimen with its obverse representing this species is from Linton, Ohio. It formed a part of the collection of Dr. J. S. Newberry and is now in the Zoölogical Collection of Columbia University, New York City.

### TUDITANUS MINIMUS sp. nov.

(Fig. 10)

The form represented by the above-named species is preserved on one side of a slab of slate, belly downward, from Cannelton, Pennsylvania. The obverse slab has been lost, which is very unfortunate, since there is no doubt that the entire skeleton was preserved. The species is placed in the genus *Tuditanus* on account of the close resemblance to the type form *T. punctulatus* Cope, although it is much smaller than that species. It is in fact the smallest of the Microsauria which the writer has thus far studied.

*Tuditanus minimus*, as the name implies, is not only the smallest member of the genus but of the suborder as well, as has just been stated. It did not attain a total length of more than three and one-half inches. Its form is very lizard-like but its structure is typically stegocephalan. The form of the skull is especially similar to that of the type species *T. punctulatus* which it resembles in the narrow posterior truncation of the skull, as well as in the anterior position of the orbits.

The skull is in the form of a narrow oval, sharply narrowed posteriorly and truncate. The orbits are located well forward and their

posterior border lies in front of the line dividing the skull transversely into equal parts. The interorbital space is greater than the diameter of the orbit. Impressions of teeth are preserved on the premaxillae and maxillae (Fig. 10). There are eight of them in a distance of three millimeters. The teeth appear to be mere blunt denticles and were possibly pleurodont.

The elements of the cranium are very poorly preserved. It has been impossible to determine all of the sutures. The bones of the premaxillary region have been destroyed but the arrangement of them was probably not far different from that which obtains in other members of the genus. The posterior boundaries of the nasals are preserved and prove this element to have had an obtuse posterior border. The sutures bounding the frontals are clear and show that they were small and that they formed a part of the inner boundary of the orbits. The parietal is recognized as a large element, apparently the largest in the

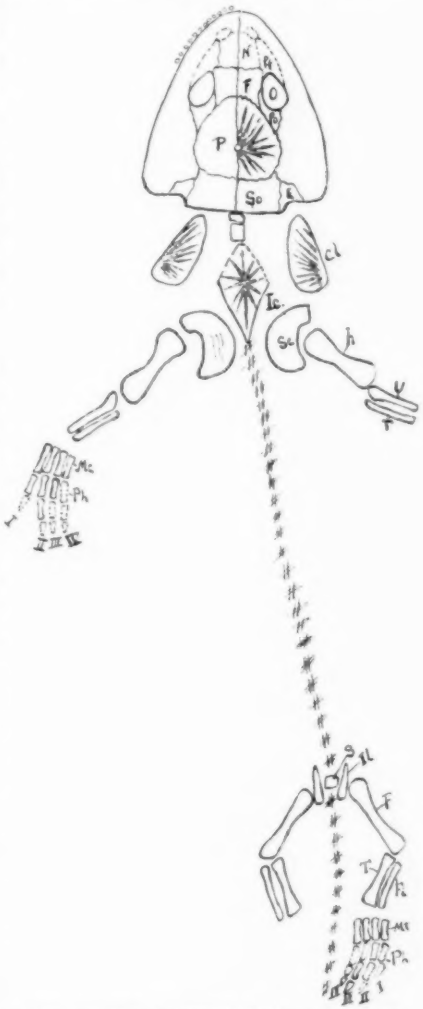


FIG. 10—The skeleton of *Tuditanus minimus* as it is preserved on the black slate. The lettering as in figure 5. ×2.

skull. Together the parietals form a wide oval inclosing on the median suture the circular pineal foramen. The parietals are sculptured with coarse radiating grooves and ridges much after the manner of *T. radiatus*. The pittings present on that form are, however, absent here. The sutures bounding the supraoccipital are tolerably well assured and these show that element to have been rather large, quadrate and with the usual relations for the element. The epiotic is distinct. It is triangular and small. It is produced into an angle on the posterior border strongly recalling a similar condition in *T. punctulatus* Cope. The boundaries of the prefrontals and the upper borders of the maxillae are not clearly ascertained. They may have had the outline indicated (Fig. 11). The lachrymal has not been detected. The postfrontal and postorbital form the posterior boundary of the orbit although the limits of the latter element have not been definitely ascertained. The position of the squamosal is well assured, although its entire boundaries are not determined. It has the usual relations of the squamosal and joins the parietal broadly. The jugal is broad and widens posteriorly to abut on the supratemporal which, as usual, forms the quadrate angle of the skull. The sutures bounding the quadratojugal and the posterior end of the maxilla are not determined.

There are but two fragmentary vertebrae preserved and an estimate based on the length of these remains gives about thirty presacral vertebrae. The structure of the vertebrae preserved cannot be ascertained but the neural spines appear to have been low and stout.

There are six elements of the pectoral girdle preserved. These are: the two clavicles, the interclavicle, the coracoid of one side and the scapulae. The interclavicle is rhomboid in form and acuminate posteriorly. It is sculptured with radiating grooves and ridges. The interclavicle is different from the same element in *T. punctulatus* Cope in that the base is acuminate, not truncate, as in the latter form. The clavicles present much the same shape as does that element in *T. tabulatus* Cope. It is ornamented by a sculpturing of radiating lines which take their origin from the lower external angle as the bone lies in the matrix. The clavicle is somewhat triangular in shape and lies close to the skull, but this close approximation of the pectoral elements to the cranium is due probably to post-mortem shifting since

the scapulae are shifted as far backward. There can be little doubt however that the pectoral arch was not far removed from the cranium. There is an oval fragment preserved on the left of the specimen which I take to be a portion of the coracoid. The scapula is preserved entire on the left side and it is represented by fragments on the right side. It is almost semicircular in form and narrows externally until it is somewhat fan-shaped. There appears to be an ornamentation of lines on the surface of the bone. These lines follow the contour of the anterior border.

The forearm is represented nearly complete on the left side and the right side shows the humerus and the forearm. The humeri are unusual in that they have well-developed articular ends as though the development of the endochondral tissue was well developed in the form. The humerus is expanded at the ends and it is larger at the upper than at the lower end. The ulna is expanded at the proximal but is more attenuated at the distal portion. It is shorter than the humerus by about one-third of its own length. The radius is a mere slender rod of bone and presents the well-developed articular ends. It is slightly shorter than the ulna. The carpus is unossified and its position is represented by a blank space. There are phalanges of four digits preserved and this, apparently, represents the entire number of digits. There is one digit, the second, which has all of the phalanges preserved and they are four in number. The phalangeal elements like the other bones of the extremity have the articular surfaces prominent. The terminal phalanx is claw-like.

There are no ribs nor traces of them preserved and a conjecture as to their character cannot be hazarded since they are known in but two other species, in which they are curved. There is no evidence of a ventral scutellation and so far as is at present known this structure is absent from all of the species of the genus or at least it is but weakly developed. It is not present in the well-preserved *T. sculptilis* described below.

Of the pelvis the ilium alone is represented. The bone itself has disappeared and has left a depression which shows this element to have been an elongate rod very similar to that described for *Micrerpeton*. The sacral vertebra seems to be indicated by a depression between the iliac depressions.

One hind limb is preserved nearly entire and the greater part of the other is also preserved although the phalangeal elements are somewhat disturbed. The femur is slender and more elongate than the humerus. It has well-formed, rounded, articular ends. The tibia presents unusual characters in that its ends are truncate as though the cartilage composing its articular surfaces was not so highly calcified as in the other limb bones. It is somewhat expanded at the ends and is throughout its length broader than the femur. The fibula like the tibia is a slender rod of bone although it is somewhat shorter than is that element. The tarsus is unossified and its position is occupied by a blank space. Portions of both feet are preserved, but only one digit in the right foot is complete. The elements of the other digits are restored. The metatarsals are elongate and slightly expanded at the ends. There are four phalanges present in the complete digit which may represent the third but more possibly the fourth, and the first digit is wanting. The only terminal phalanx preserved is claw-like.

MEASUREMENTS OF *Tuditanus minimus* MOODIE

| | mm |
|---|---|
| Median length of skull | 15 |
| Width of skull at posterior border | 16 |
| Length of orbit | 3·5 |
| Width of orbit | 2 |
| Interorbital width | 2·5 |
| Length of clavicle | 6 |
| Width of clavicle, maximum | 3·5 |
| Length of interclavicle, estimated | 5 |
| Width of interclavicle | 3·5 |
| Length of scapula | 3·5 |
| Width of scapula, maximum | 2·5 |
| Length of coracoid (?) | 2 |
| Length of humerus | 4 |
| Length of radius and ulna | 3 |
| Length of metacarpal | 1 |
| Length of ilium | 2·5 |
| Length of femur | 4·5 |
| Length of tibia and fibula | 3 |
| Length of foot | 3·5 |
| Length of metatarsal | ·75 |

The specimen is from the Cannelton slates, Middle Kitanning, near Cannelton, Pennsylvania. It is No. 4,555 of the U. S. National Museum Collection.

### TUDITANUS SCULPTILIS sp. nov.

(Figs. 11, 12)

There is preserved in the collections of Walker Museum a small amphibian skull pressed flat on a slab of slate from Cannelton, Penn-

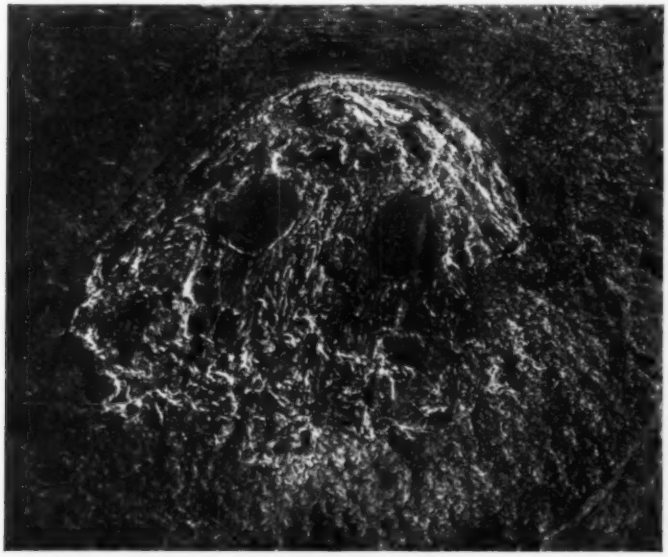

FIG. 11.—The skull of *Tuditanus sculptilis* as it is preserved on the slate. ×3.

sylvania. This specimen formed a part of the Hall Collection recently acquired by the University of Chicago. It is No. 12,315, U. of C.

The specimen presents only a portion of the skull and fragmentary pectoral plates. The skull is wider than long and the muzzle is broadly rounded. The orbits are narrow ovals and their posterior border falls on the transverse line dividing the skull equally. The interorbital width is slightly greater than the width of the orbits and about equal to their length. The posterior outline of the skull is

somewhat truncate as in *T. tabulatus* Cope and other species of the genus. The distal extremities of the quadrates do not project as far backward as do the supraoccipitals. The skull roof is formed of the regular elements except that a quadrate seems to be indicated by a scale of bone on the posterior angle. The nostrils are oval and the pineal foramen is small.

The premaxilla is probably a relatively large element though its boundaries are not definite. The nasal is of an oblong shape and

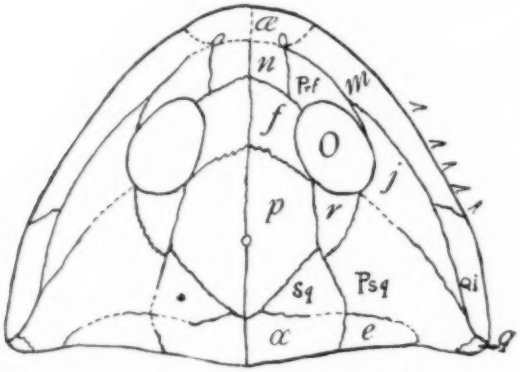


FIG. 12.—The elements of the cranium of *Tuditanus sculptilis*. Ae = premaxilla; e = epiotic; f = frontal; j = jugal; m = maxilla; n = nasal; O = orbit; p = parietal; q = quadrate; qj = quadratojugal; Psq = supratemporal; r = postfrontal; sq = squamosal; prf. = prefrontal.

borders the frontal anteriorly. The frontal forms the whole of the interior border of the orbit and borders the parietal broadly behind. The parietal is a large element and the pineal foramen is inclosed in the median suture about midway of the parietals. The supraoccipital is wider than long and with the epiotic forms the greater part of the posterior border of the skull. The prefrontal apparently forms the entire anterior border of the orbit and sends an acuminate projection to the side of it. The maxilla is excluded from the orbit and is an elongate element with sharp conical teeth of which there are four preserved. These measure about one millimeter in length. The jugal lies along the lateral border of the orbit and it is acuminate both anteriorly and posteriorly. It borders the supratemporal

broadly. The postorbital has not been detected. The postfrontal forms the greater part of the posterior boundary of the orbit. It is triangular and acuminate behind. It is bordered broadly by the parietal and supratemporal. The squamosal element is also triangular and it borders the parietal broadly. The supratemporal is evidently the largest element in the skull and on its posterior corner there is a flake of bone which may represent the quadrate though this is by no means certain. The quadrate has not been detected in any of the Carboniferous Microsauria so far studied although it is well developed in the Permian microsaurian, *Diplocaulus*. The epiotic is an elongate element in the transverse line of the skull. Its entire boundary is uncertain though a part of the sutures are present. The quadratojugal is elongate and lies posterior to the maxilla and with that element forms the lateral border of the skull.

The canals of the lateral line system have not been detected on the skull. The sculpturing of the cranial elements consists of grooves and ridges which radiate from a center. They are more prominent on the parietals than elsewhere although the other skull elements present a strong sculpturing.

There are also preserved on the slab of slate about ten millimeters posterior to the skull fragments of pectoral plates, probably representing the clavicles and interclavicle. They are so badly fractured that the form cannot be determined. No limbs or vertebrae have been observed.

MEASUREMENTS OF THE SKULL OF *Tuditanus sculptilis* MOODIE

| | mm |
|---|---|
| Length of the skull in median line | 20 |
| Width of skull at posterior border, estimated | 24 |
| Diameter of orbit | 3 |
| Length of orbit | 4 |
| Interorbital space | 4 |
| Diameter of nostril, less than | 1 |

Pineal foramen about one-half mm in diameter.

### DICERATOSAURUS LAEVIS sp. nov.

(Figs. 13, 14)

The genus Diceratosaurus was established by Jaekel[1] for the reception of the species described by Cope as *Cerater peton punctoline-*

[1] *Neues Jahr. Mineral.* 1903, p. 112.

*atum* from the deposits of Linton, Ohio. There are good evidences that the species does not belong in the genus *Ceratorpeton* and Jaekel's genus will undoubtedly stand. There are now known three species of this group, two of which are described herewith.

FIG. 13—The skull of *Diceratosaurus laevis* ×2.

The species *Diceratosaurus laevis* is represented by an almost perfect skull (Fig. 13) in the American Museum collection. It is from the mines at Linton, Ohio and had been identified by Cope as *Tuditanus radiatus*. The specimen consists of the bones of the cranial roof, the bones themselves having disappeared. It is not probable that the skull bones were smooth. The details in the structure of the skull have all been ascertained quite definitely, and there can be no doubt that the arrangement of the cranial elements as shown

in Fig. 14 is accurate. As in *Tuditanus tabulatus* Cope the squamosal is excluded from the parietal.

The form of the skull at once recalls that of the species *D. punctolineatus* Cope as figured by Jaekel. The orbits are located in nearly the same region of the skull and the sutures separating the cranial elements are quite similar in the anterior region of the skull. The species *D. laevis* is based on the divergent character of the horn-like protuberances which project from the supratemporals. The horns of *D. punctolineatus* Cope are convergent. The present skull is also smaller and the parietals in *D. laevis* are much larger than in the type species. In the type species also the pineal foramen is located well forward in the parietal while in the present form the foramen is located well posterior.

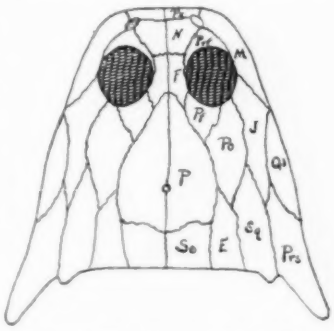


FIG. 14.—The elements of the cranium of *Diceratosaurus laevis*. E = epiotic; F = frontal; J = jugal; M = maxilla; N = nasal; P = parietal; Pf = postfrontal; Prf = prefrontal; Po = postorbital; Prs = supratemporal; Px = premaxilla; Qj = quadratojugal; So = supraoccipital; Sq = squamosal. ×1.

The skull is almost rectangular. The nostrils are elongate ovals. The orbits are circular and the distance between them is equal to two-thirds of the dimension of the orbit. They are located well forward in the skull and are bounded laterally by the maxillaries. The parietal foramen is situated in the posterior third of the parietals. The nostrils have much the same character as in the type form. They are broadly oval.

The premaxillae are elongate transversely being about twice as long as wide. They are identical in shape and relations with the same elements in *D. punctolineatus* Cope. The nasal is nearly square and forms the interior boundary of the nostril. The frontal is elongate in the median length of the skull and it is acuminate posteriorly where the acumination is inclosed by the parietal and postfrontal. The parietals are by far the largest elements in the cranium. They form together an oval which is elongate in the longitudinal diameter of the

skull. They inclose between them in the median suture the small pineal foramen. They are acuminate in front with a broad truncate posterior base where they are bounded by the supraoccipitals. The supraoccipital is nearly square, being somewhat wider than long. It joins the epiotic and the parietal. The epiotic is elongate in the longitudinal diameter of the skull. It ends anteriorly in a point which is inserted between the postorbital and the parietal. The epiotic bears a short protuberance posteriorly much as does the same element in the type species. There are four elements which take part in the formation of the posterior border of the skull. These are: the supraoccipital, the epiotic, the squamosal and the supratemporal. It is very unusual for the squamosal to reach the posterior edge of the cranium. The prefrontal lies anterior to the orbit of which it forms the anterior border. It has the usual relations. The lachrymal has not been detected although Jaekel[1] has identified it in his drawing of the skull of the type species. The maxilla is elongate and forms the lateral border of the skull. No teeth have been detected although they were doubtless the same as Jaekel has figured in *D. punctolineatus* Cope. The jugal is an elongate element joining the maxilla posteriorly. Jaekel included this element in his "perisquamosal" but the sutures are clearly evident in this specimen and no "perisquamosal" has been identified. The postorbital is fully as large as the jugal which it joins. It forms a part of the posterior border of the orbit and it ends posteriorly in a point which is inclosed by the epiotic and the squamosal. The postfrontal with the foregoing element forms the entire posterior border of the orbit and it likewise ends in a point inclosed by the parietal and the postorbital. The quadratojugal has much the same shape and relations as in *D. punctolineatus* Cope, although it is located farther back. The squamosal is also elongate as are most of the posterior cranial elements and it likewise has an acumination which is directed forward and is inclosed by the postorbital and the jugal. The squamosal abuts onto the posterior border of the skull. The anterior suture of the supratemporal element is rather indistinct but it is, I believe, as represented. The element is elongate and is prolonged posteriorly to form the horn, which ends in a blunt point and is not sharp as in the type species.

[1] *Op. cit.*

On the basis of the "perisquamosal," which Jaekel claims for *Diceratosaurus punctolineatus* Cope, the genus was regarded by that author as without a parallel among the known vertebrates. Such it would be if Jaekel's interpretations are correct but the morphology of the present skull would tend to throw grave doubt on the interpretation of this region of the skull as given for the type species. Another specimen representing another species also shows no evidences of the fusion of elements to form the "perisquamosal" and its presence in the type species is doubtful. So far as I can learn there has never been a true case of fusion in any of the cranial elements of the Stegocephala unless it be between the frontals of *Diplocaulus magnicornis* Cope, and I think I can detect a median suture even here. It was on the basis of such fusions that Maggi has proposed to derive the interparietal of the primates from the epiotics of the stegocephalans.

The posterior outline of the skull in the present specimen is not well preserved and the outline as given may be slightly inaccurate. The indentation figured by Jaekel in the posterior border of the skull of the type form is not present in the species under discussion.

MEASUREMENTS OF THE SKULL OF *Diceratosaurus laevis* MOODIE

| | mm |
|---|---|
| Length of skull along median suture | 37 |
| Length from muzzle to tip of horn | 50 |
| Width between tips of horns, estimated | 40 |
| Width of orbit | 7 |
| Length of orbit | 10 |
| Width of skull across the orbits | 30 |
| Interorbital width | 6 |
| Length of nostril | 2 |
| Width of nostril | 1 |
| Diameter of the pineal foramen less than | 1 |

The specimen on which the species is based is from the Linton deposits of Ohio and forms a part of the collection of Dr. J. S. Newberry now in the American Museum. It is No. 102 of the American Museum Collection.

### DICERATOSAURUS ROBUSTUS sp. nov.
(Fig. 15)

The present species is indicated by the left portion of a cranium representing a large individual. The characters of the skull are so

clearly marked that it seems worthy of description. The presence of horns as given in the restoration of the skull is based on the analogy with the other two species of this genus in both of which horns are present. The generic determination of the species is based on the large size of the postorbital which is essentially characteristic of the other species of *Diceratosaurus*.

The characters which distinguish the species from the others of the genus are the large postorbitals and the small parietals which are excluded from union with the postfrontals on account of the large size of the frontal. In the other two known species the frontal is small and the parietal comes forward to join the postfrontal. The present species exhibits a skull which is nearly twice as large as that of *D. laevis* and nearly three times the size of the skull of *D. punctolineatus*.

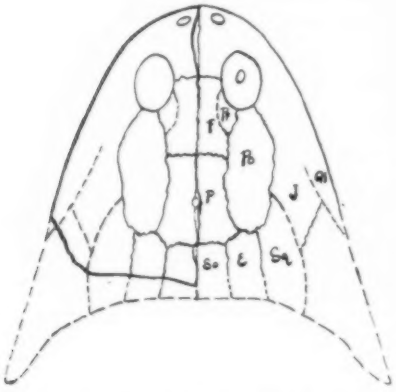


FIG. 15.—The skull of *Diceratosaurus robustus*. E = epiotic; F = frontal; J = jugal; Pf = postfrontal; P = parietal; Po = postorbital; Qj = quadratojugal; So = supraoccipital; Sq = squamosal.

The portion of the skull preserved shows the cranium to have had a rather acuminate snout, not blunt as in the type species. The orbit is an elongate oval although it has the same relative position in the skull as in the other species. The nostril is indicated by an oval depression near the anterior edge of the skull. The frontals as indicated by the sutures present on the portion of the skull preserved are fully as long as the parietals. Whether they were as wide as is represented in the drawing (Fig. 15) is uncertain. The postfrontals are represented by very small bones the sutures of which are somewhat uncertain although they cannot be far from what is represented in the drawing. The postorbital is large and elongate. It is distinctive of this species on account of its unusual size and of the genus as well,

although it does not attain such proportions in the other known forms. The parietals are elongate and narrow. The pineal foramen is represented by its lateral edge and its position is about midway of the longitudinal diameter of the parietals. The supraoccipital is represented by its anterior border. It is narrow. As restored it may be too long. The epiotic also is represented by an anterior portion and it shows this element to have the position and form which is typical of the form *D. laevis*. Such other of the cranial elements as are indicated are based on the relations discovered in *D. laevis*.

The heavy line on the left of the drawing represents the outline of the portion preserved. The skull, as restored, may be a little too long, and the shape of the horns is conjectural. In the orbit there are preserved two teeth showing longitudinal fluting. The longest tooth is about three millimeters.

MEASUREMENTS OF THE SKULL OF *Diceratosaurus robustus* MOODIE

| | mm |
|---|---|
| Median length of the skull, estimated | 67 |
| Posterior width of the skull, estimated | 78 |
| Length of orbit | 18 |
| Width of orbit | 12 |
| Length of postorbital | 27 |
| Width of postorbital | 14 |
| Length of longest tooth | 3 |
| Width of same tooth at base | 15 |

This specimen is from the coal mines of Linton, Ohio. It forms a part of the Newberry collection of the American Museum where it is No. 8,611 G.

ICHTHYERPETON SQUAMOSUM sp. nov.

The present species is based on well-preserved remains from the Linton, Ohio, beds. There are two specimens of the species preserved on blocks of bituminous coal and they represent the greater length of the animal. The species is located in the genus *Ichthyerpeton*, which was based by Huxley[1] on remains from the Coal-measures of Ireland (Fig. 16), on account of the character of the dermal covering which consists of small overlapping scales such as

[1] *Trans. Roy. Irish Acad.*, 1867, p. 351.

Huxley described for the form from Ireland. The specific characters of this form are the small size of the rounded scales, the attenuated tail, the apparent absence of limbs, the character of the ventral scutellation and the slightly curved condition of the ribs.

From the preserved remains it is estimated that the animal attained a length of not less than three feet and its body was long and slender and it may have had an appearance similar to that of a *Siren* or a *Proteus*. The slenderness of the body is a variance from the condition found in the type species, *Ichthyerpeton bradleyae* Huxley (Fig. 16)

FIG. 16.—The impression of *Ichthyerpeton bradleyae* Huxley. After Huxley.

in which the trunk was rather stoutly built. The character of the anterior portion of the body in the present species cannot be determined and the skull is wanting. There are no evidences of anterior limbs although the ventral scutellation preserved would seem to include the pectoral region. No pectoral shields are preserved nor are there any traces of pelvic elements or limbs.

The preserved portions on one block include nearly the entire tail and the posterior of the body and on the other block the dorsal region of the body and the anterior portion of the tail, so that the specimens supplement each other in an interesting manner. There are impressions of several vertebrae preserved. They are much of the same character as Huxley has described for the type species. They are short and thick and were probably amphicoelous. There are preserved the remains of rather slender recurved ribs mingled in with the

remains of the ventral scutellation and distinguished from the elements of the abdominal shield by their size and curvature. They were apparently single-headed, but the character of their articulation cannot be determined. The ventral scutellation consists of fine continuous rods arranged in the regular chevron pattern. They do not seem to be divided into oat-shaped scutes as is the case with the form described by Huxley. The ventral rods are closely packed for a distance of more than six inches but as they are scattered their exact arrangement cannot be determined. They seem to have extended to the cloacal region but there are no evidences of the specialized clasping organs such as are developed in the ventral armature of *Ophiderpeton*. The scales which are well preserved on the tail, may have covered the entire body since there are many scattered scales in the dorsal region of one of the specimens. The scales are slightly oval, tuberculate, and they measure scarcely one millimeter in their longest diameter. They show but slight evidences of having been imbricated though they may have been so although they may have been inclosed in the integument and somewhat separated from each other. The most posterior part of the tail preserved seems to indicate that the tip was attenuated. It was probably flattened from side to side. We may thus regard *Ichthyerpeton squamosum* as an elongate aquatic animal with a long flattened tail, and since there were possibly no limbs it would be an animal highly adapted for life in the water. The present species is of interest because it represents for the first time the discovery of the scaled Amphibia in the deposits of North America.

MEASUREMENT OF THE TYPES OF *Ichthyerpeton squamosum* MOODIE

| | |
|---|---|
| Length of the animal as estimated from the two impressions | 3 feet |
| Length of longest impression | 21 inches |
| Length of specimen containing tail impression | 9 inches |
| Width of tail impression, maximum | 50 mm |
| Width of tail impression, minimum | 6 mm |
| Width of a single scale | 1 mm |
| Chevron rods in a distance of three mm | 8 |
| Distance from base of tail to the tip | 125 mm |
| Width at base of tail | ∞ |

SECOND SPECIMEN

| | |
|---|---|
| Length of specimen as preserved | 225 mm |
| Width of chevron rod space | 30 mm |
| Length of rib | 25 |

The species is based on two specimens which form part of the Lacoe collection belonging to the U. S. National Museum where they are Nos. 4,476, and 4,459. The specimens are preserved on two blocks of bituminous coal from the mines at Linton, Ohio.

## MACRERPETON HUXLEYI Cope

(Fig. 17)

The new genus *Macrerpeton* is proposed for the reception of the species of amphibian described by Cope as *Tuditanus huxleyi.*[1] This form he placed provisionally in the genus *Tuditanus* since it seemed to present the same type of sculpturing of the cranial elements similar to that found in *T. radiatus* Cope. Even this species, in all probability does not belong in this genus but it cannot be removed at present. Closer study of the type specimen of *Tuditanus huxleyi* Cope shows great variation from any of the species described from Linton, Ohio, and indeed from any Carboniferous form thus far known.

The specimen represents the left side of the face of a form which seems to approach the higher labyrinthodonts in the shape of the skull. The orbit is far removed from the border of the skull and taking the median line of the skull as somewhat further inward than the part preserved we have a skull which cannot be far from the figure (Fig. 17). The left posterior angle of the skull seems to be represented by a depression on the face of the block of coal on which the specimen reposes. The arrangement of the bones as given in the diagram (Fig. 17) strongly recalls that of *Capitosaurus* from the Keuper of Europe. The anterior border of the skull is restored after the skull of *Capitosaurus* but the skull may have been pointed as in *Archegosaurus*. The character of the teeth would seem to be such as to refer the form to a labyrinthodont. The teeth are very

[1] *Rept. Ohio Geol. Surv.*, 1875, p. 397.

strong and curved backwards and they have the strong longitudinal fluting which is characteristic of many of the labyrinthodonts. Another character which would distinguish the form is the pattern of the cranial sculpture. This consists of inosculating pits and grooves

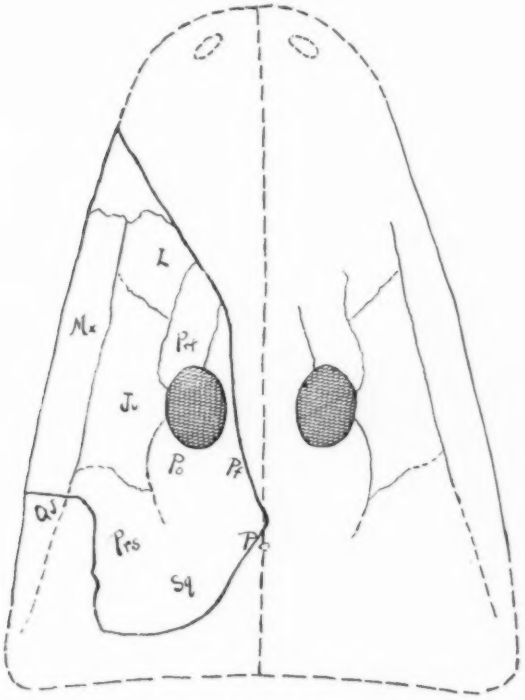


FIG. 17.—Restoration of the skull of *Macrerpeton huxleyi* Cope. One-half natural size.

of a coarse character and compares favorably with the sculpturing of the later forms like *Anaschisma* from the Trias of Wyoming. If this form really represents a labyrinthodont-like form it is the oldest of the kind so far known since in all probability the *Eosaurus* vertebrae come from a higher horizon. The specific characters have been given by Cope and further discussion will be deferred.

SAUROPLEURA LONGIDENTATA sp. nov.
(Figs. 18, 19)

This species may be distinguished from the other members of the genus by the large size and shape of the cranium and by the broad mandible with its very long teeth. The skull of *Sauropleura digitata* Cope is not known but the body of that animal as preserved represents far too small a form for the skull to be referred to that species. The skull of the present species is fully half as long as the dorsal region of *S. digitata* Cope so that an association of the remains would be incongruous. From the skull of *S. scutellata* Newb. the present skull differs in size and proportions. The skull of *S. scutellata* is narrow while the skull of *S. longidentata* is quite broad. The teeth of the latter are characteristic of the species since in all of the other species of the genus where the skull is preserved the large anterior tooth is wanting.

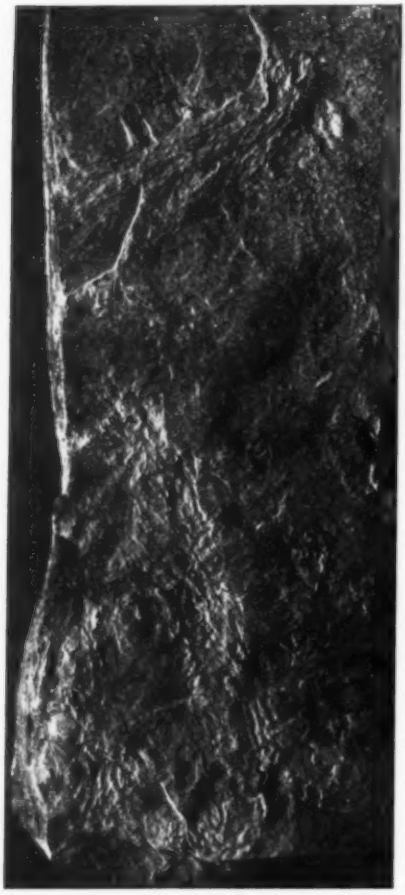

FIG. 18.—The type specimen of *Sauropleura longidentata*. Natural size.

Of the species *Sauropleura longidentata* there is preserved the right half of a cranium (Fig. 18) and the greater portion of the mandible belonging to the same individual. The bones

show the coarse sculpturing of the larger species of the Microsauria and it consists more of radiating grooves than of pits. The skull, as restored, is broadly ovate, with the posterior border truncate. The muzzle is broad and the nostrils are, apparently, located near the anterior margin. The pineal foramen cannot be detected. The posterior border of the orbits lies near the median transverse line of the skull. They are circular and are removed some distance from the margin of the cranium. Only the frontal and parietal can be

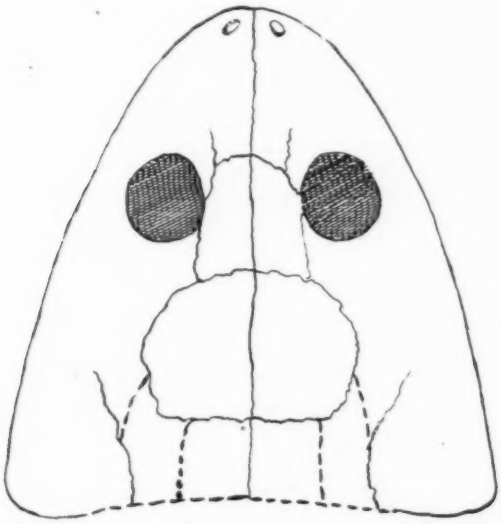

FIG. 19.—The cranium of *Sauropleura longidentata*. Natural size.

determined with certainty. These are seen to be rather large and have the usual relations of those elements.

The lower jaw is heavy and it is provided with heterodont teeth, which were possibly pleurodont, though this cannot be determined since the specimen lies on its inner side. Near the anterior end of the mandible there is a very long fang-like tooth, longitudinally striated, which rises from a broad base and rises to considerable prominence. It is slightly recurved. The other teeth are smaller though the next

succeeding one is still of considerable size. All of the teeth preserved are longitudinally striated but only the two anterior ones are recurved to any extent.

MEASUREMENTS OF THE TYPE OF *Sauropleura longidentata* MOODIE

| | mm |
|---|---|
| Length of the skull in median line | 75 |
| Width of skull at posterior border, estimated | 80 |
| Width of skull across orbits, estimated | 60 |
| Width of orbit | 10.6 |
| Length of orbit | 12 |
| Interorbital space | 16 |
| Length of jaw, as preserved | 48 |
| Width of jaw, maximum | 16 |
| Width of jaw, minimum | 5 |
| Length of longest tooth | 11 |
| Width of longest tooth at base | 4.5 |
| Length of shortest tooth | 3 |
| Width of shortest tooth at base | 1 |

This specimen forms a part of the Newberry collection of the American Museum of Natural History where it is No. 8,619 G.

### EOSERPETON TENUICORNE Cope gen. nov.

(Fig. 20)

The new genus *Eoserpeton* is erected for the reception of a single species originally described by Cope as *Ceraterpeton tenuicorne*. It cannot be placed under the genus *Ceraterpeton*, however, on account of the form and structure of the skull which varies widely from that of the type species of *Ceraterpeton*, *C. galvani* Huxley. The most important character in which the present species differs from *C. galvani* Huxley is the peculiar form taken by the prosquamosal as well as the fact that it is the epiotic which has the horn-like projection in *C. galvani* Huxley while in *Eoserpeton tenuicorne* Cope it is the supratemporal which bears the projection. The present species also lacks the projection at the side of the skull which is characteristic of the *Ceraterpeton*. No undoubted remains of the genus *Ceraterpeton* occur outside of England and Ireland, so far as I am aware. Fritsch referred a species, provisionally described as *Scincosaurus crassus*, to this genus but Andrews, Jaekel, and Woodward all agree that the species does not belong under *Ceraterpeton*. Jaekel even says there

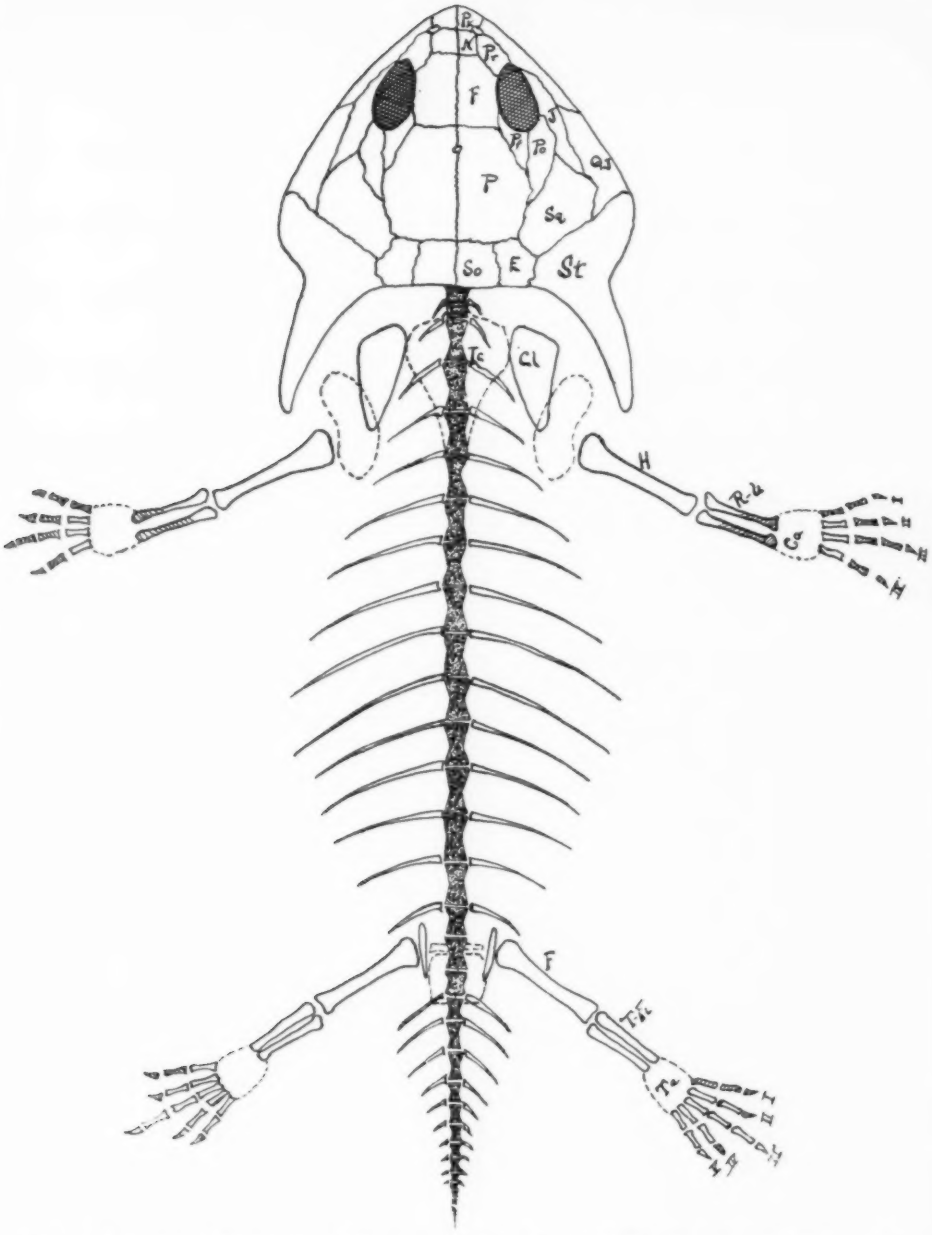


FIG. 20.—A restoration of the skeleton of *Eoserpeton tenuicorne* Cope. The lettering as in other figures. ×2.

are no horns in the species *Scincosaurus crassus* Fritsch. Cope described three species from the coal deposits of Ohio under *Craterpeton* but none of them belong there. Jaekel has defined one species so described, *C. punctolineatum* Cope, as *Diceratosaurus punctolineatus*

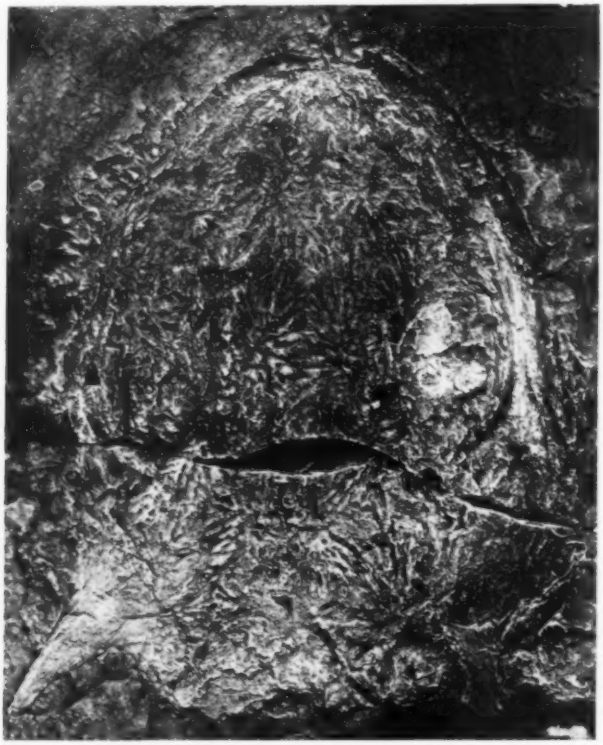

FIG. 21.—The impression of the skull of *Stegops divaricata Cope.* ×2.

Cope and the other species is described here under the new genus *Eoserpeton*. The new genus is characterized from *Diceratosaurus* of Jaekel by the divergent character and shape of the horns, the shape and organization of the skull and by the form and position of the orbits.

The restoration of the species *Eoserpeton tenuicorne* Cope is based

on three specimens two of which represent the larger part of the animal and the other is a large skull in which the characters of the cranium have been detected. The two specimens in the National Museum at Washington (Nos. 4,472 and 4,473) are impressions of the same individual. It differs from the specimen in the horns being slightly incurved as represented in the drawing. This latter form was described by Cope in 1897.

STEGOPS DIVARICATA Cope gen. nov.

(Figs. 21, 22)

The genus *Stegops* has been erected for the reception of the peculiar form described below. This species was first described by Cope as *Ceraterpeton divaricatum*[1] but there are very good reasons why the form cannot be retained in this genus nor can it be placed in either the genus *Eoserpeton* or *Diceratosaurus*. The entire shape of the skull, the character of the horns and the presence of a large lachrymal are distinctive characters of the new genus *Stegops*.

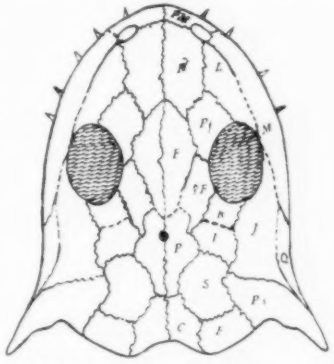

FIG. 22.—The outline of the cranial elements of *Stegops divaricata* Cope. The lettering as in other figures except I = intertemporal (?). ×1.

The remains on which the new genus reposes consist of the impressions of a single well-preserved skull from the coal mines at Linton, Ohio. The chief characters which distinguish the genus will also serve to differentiate a new family of Microsauria which may be known as the STEGOPIDAE. The chief family characters are the large lachrymal unknown in any of the other species of Carboniferous Amphibia, the central position of the orbits, the general form of the skull, and the peculiar short divaricate horns. If an intertemporal element is present in the skull, which is suggested as a possibility, the family is further distinct.

[1] *Proc. Amer. Phil. Soc.*, 1885, p. 406.

SAURERPETON LATITHORAX Cope gen. nov.

(Fig. 23)

The new genus *Saurerpeton* is erected for the reception of the species described by Cope in 1897[1] as *Sauropleura latithorax*. The characters which distinguish the genus not only from *Sauropleura* but from all other known Microsauria are the broad plate-like character of the ventral scutellation, the broad rounded character of the pectoral plates, and the broad short skull. The structure (Fig. 23) of the skull

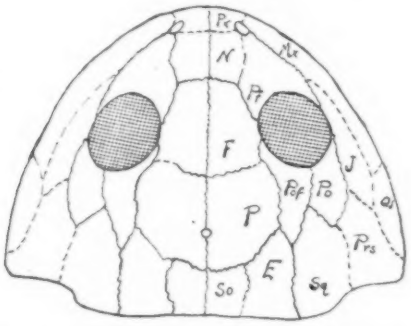


FIG. 23.—Outline of the cranial elements of *Saurerpeton latithorax* Cope. Less than natural size.

is nearest to that of the genus *Diceratosaurus* but the present form lacks the horns and the shape of the skull is also far different from that of the species of *Diceratosaurus*.

The skull of *Saurerpeton latithorax* Cope is broad and heavy. The teeth are heterodont. The body is broad and stout and the limbs are of unusually strong proportions. The ventral armature consists of broad imbricating scutes which form a single piece across the abdomen and are but slightly angulated to form the chevron. All other known Microsauria have the chevron armature strongly angulated and the scutes are usually long and slender. A distant approach to the condition of *Saurerpeton* is found in the *Ctenerpeton*, but the peculiar comb-like expansions and the shape of the body in the latter distinguish the two forms.

[1] *Proc. Amer. Phil. Soc.*, 1897, p. 86.

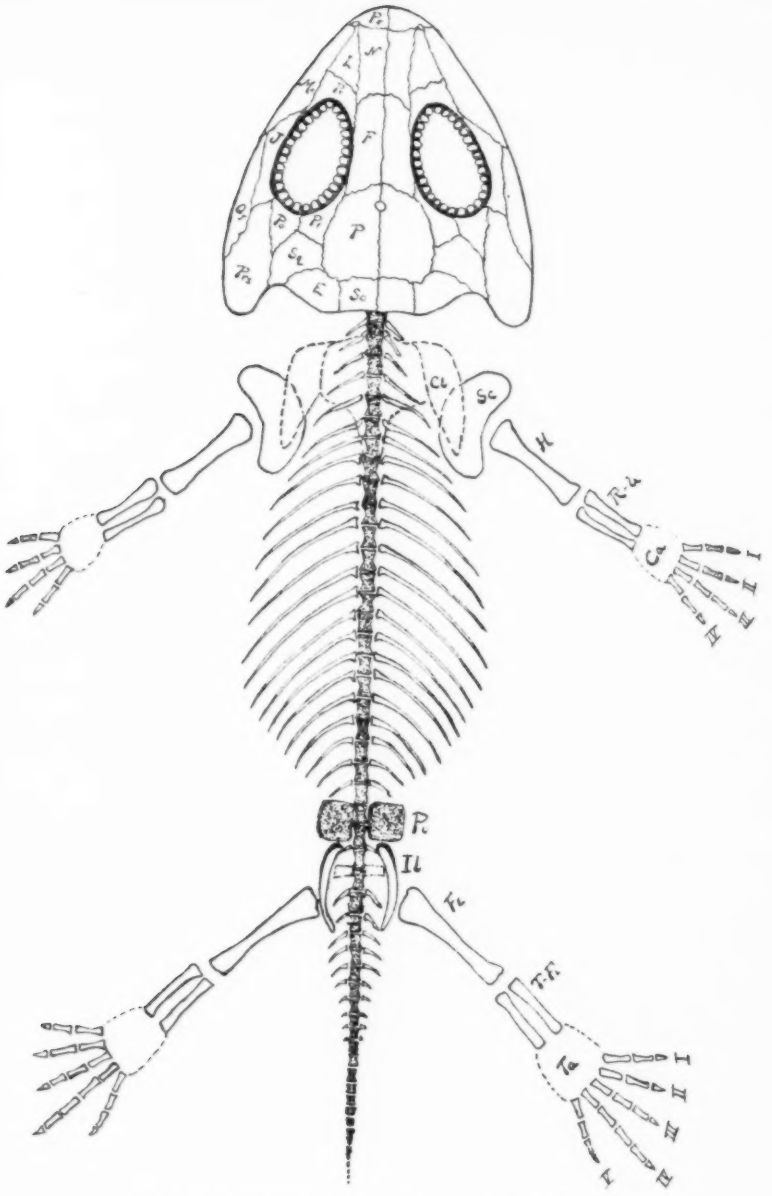


FIG. 24.—A restoration of *Amphibamus grandiceps* Cope.

### AMPHIBAMUS GRANDICEPS Cope

(Fig. 24)

This well-known species from the Mazon Creek deposits is restored herewith. The restoration is based on a specimen, nearly complete, in the collection of Mr. L. E. Daniels of LaPorte, Ind., and on the drawings of Cope.

In conclusion I wish to express my hearty appreciation to Drs. S. W. Williston and Stuart Weller for the interest they have taken in my work and for the help I have received from them.

# THE ANCIENT KOBUK GLACIER OF ALASKA

OSCAR H. HERSHEY
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Between Hotham Inlet and Kotzebue Sound, on the Arctic coast of Alaska, there is a long narrow strip of rolling upland which is probably (in part at least) a glacial moraine. The portion I saw in the summer of 1906 (from Cape Blossom north) consists of broad, smooth ridges, probably rising 50 to 150 feet above sea-level, bordered on the west and north by a sea-cliff from 30 to 100 feet high. The tundra vegetation on the upland surface completely obscures the nature of the underlying material, but its character may be inferred from many fairly good exposures in the sea-cliff.

The northwestern corner of this upland is protected from present marine erosion by a triangular strip of lowland bordered by a beach ridge from 5 to 12 feet high, behind which there are lagoons and marshes. The Friends' Mission at Kikiktak or Kotzebue Post-office is situated on the beach ridge near where it makes a sharp bend from north to east and about one and one-half miles from the old sea-cliff. The latter, where thus protected, is broken down and tundra-covered so that there are no satisfactory exposures of the underlying material.

About two miles east of the mission, the cliff presents, along a distance of half a mile, a number of imperfect exposures of typical till. It is a stiff blue-gray clay abounding in rock fragments in sizes up to eighteen-inch boulders. They consist of many rock species, but varieties of gabbro, probably derived from Mendenhall's Kanuti series,[1] are the most conspicuous. Most of the pebbles, cobbles and boulders are somewhat rounded, in the manner characteristic of glacial abrasion, noticeably differing from similar material after having been exposed for some time to wave action on the beach. Very many

[1] Walter C. Mendenhall, "Reconnaissance from Fort Hamlin to Kotzebue Sound, Alaska, by Way of Dall, Kanuti, Allen and Kowak Rivers," U. S. Geological Survey, *Professional Paper No. 10.*

of the faceted pebbles and boulders are striated; indeed, a few minutes' search yielded some of the finest scratched stones I have ever found.

Owing to the masses of tundra soil that have fallen down the cliff, the upper limit of this apparent glacial deposit is obscured but appears to be quite irregular. It is overlaid by a thick bed of dark blue-gray laminated silt and muck, which is better exposed than the boulder clay. In places the silt forms steep banks 30 feet high, reaching down to sea-level. In other places the boulder clay reaches from 3 to 6 feet above the water and at one place fifteen feet, being there overlaid by only about ten feet of silt. The fine lamination, absence of gravel or coarse sand, and the presence of much peat in the silt at first suggested to me that it was deposited in a lagoon (at a time the land was lower) behind a beach ridge which has been completely destroyed by marine erosion.

The boulder clay has a character typical of ground moraine and it is undoubtedly due to ice action. However, the question may be raised as to the method of its formation and how it reached its present position. This is especially pertinent in view of the fact that this locality is far beyond the reputed limits of Quaternary glaciation in northern Alaska. Three hypotheses are worthy of consideration. The first attributes the boulder clay to the action of shore ice. This would not account for the presence of the clay and the extensive faceting and scratching on all sides of the included rock fragments, for it is inconceivable that the shore ice could work long enough on the same material to produce these features as strongly developed as they are found.

The second hypothesis recognizes the material as till but attributes its present position to transportation by floating ice. The objection to this is that there is too much of it to have been carried *en masse* and that if carried in small quantities and dropped from time to time, it should be mixed with typical marine deposits which so far have not appeared in the exposures.

The last hypothesis, and one which I am inclined most strongly to favor, is that it is a portion of the ground moraine of a great glacier that came out of the mountainous interior of Alaska, probably covering, in part at least, the basin of Hotham Inlet.

About three miles south of the mission, the modern beach ridge approaches the sea-cliff. There are no true exposures of the material in the face of the cliff, but water-worn gravel like the present beach gravel, though probably of a different origin, occurs at several points up to 50 feet above sea-level. This is the seaward edge of a small plain about 75 feet above the sea. Less than a mile south there is a smooth ridge running inland; on its south side there is another broad flat plain extending inland half a dozen miles and probably two miles wide along the sea-cliff. Its altitude is about 75 feet above the sea; on the south it is bordered by another narrow smooth ridge running inland. A few very imperfect exposures on the sea-cliff forming the seaward edge of the plain show pebbleless brown carbonaceous silt, suggesting a lagoon deposit. It is evident to me that the depressions of a rolling upland have been filled with fine silt to a level which, possibly through uplift, is now mostly about 75 feet above the sea. Marine erosion has cut away a large part of these plains and the intervening ridges, producing a sea-cliff from 50 to 100 feet high, at the foot of which lies the modern beach ridge, generally 75 yards wide. There remains to discover the composition of the upland ridges.

At about seven miles south of the mission there is a small lagoon winding about in the marshy floor of the valley whose mouth was originally below sea-level, the 75-foot silt plain above described not being developed here. Indeed, looking over the country south to beyond Cape Blossom, it appears that the smooth ridges generally rise to about 100 feet above sea-level and are separated by valleys of varying widths, generally coming down nearly to sea-level at the beach line. Inland as far as one can see there are no isolated hill peaks; nor, on the other hand, is there a suggestion that the valleys have been eroded from a plain. The topography suggests a constructional surface of a glacial type, not that of a terminal or lateral moraine, but of an undulating ground moraine.

At about half a mile south of the lagoon, the sea-cliff, 60 to 100 feet high, bisects a broad, undulating ridge which leads inland as do the others above described. Stiff blue-gray boulder clay abounding in beautifully glaciated pebbles and boulders (the latter generally gabbro or metagabbro), appears for nearly a quarter of a mile, rising from 10 to 50 feet above sea-level and overlaid by dark blue-gray and

brown carbonaceous silt, 30 to 60 feet thick. I have no doubt that the core of this ridge and presumably of many others in this region is ground moraine. I am surprised and puzzled by the invariable presence over the till, even in the axes of the ridges, of stratified carbonaceous silt. I cannot distinguish between this silt formation and that which in places forms plains between the ridges. It is probable that only one silt formation is present, and that it has an attitude similar to the loess formation in the Mississippi basin, mantling an undulating drift plain. Therefore, the theory that it is a lagoon formation must be abandoned.

(At the upper edge of the bank, on the north side of the ridge south of the lagoon, I found the pelvis of a large animal. It was 8 feet wide. It had evidently been embedded in the soil at the surface of the silt formation.)

A headland about three and one-half miles northeast of the mission presents a 100-foot sea-cliff at the base of which, in places reaching up to 20 feet, occurs the blue-gray till abounding in glaciated boulders, some four feet in length. They consist chiefly of gabbro, metagabbro, pyroxenite, greenstone, diorite, gneiss, schist, marble, limestone, and fine-grained sandstone. The overlying non-pebbly carbonaceous silts form the greater portion of the cliff, but are not well exposed.

Three-fourths of a mile farther northeast, the cliff in a headland is only from 30 to 50 feet high, yet the boulder clay reaches up to 20 feet above sea-level. Boulders from one to three feet in diameter are relatively more abundant than at the outcrops before described. The largest is a dark green altered fine-grained basic volcanic rock.

At "the cape," the bold headland five miles northeast of the mission, that forms the most northerly point of the peninsula, although the sea-cliff is probably 150 feet high, the silt is so thick that the boulder clay does not appear to extend more than about 15 feet above sea-level. From the top of the cliff looking inland two peculiar depressions can be seen. They are occupied by lakes which may be between five and ten acres in extent. The northern side of each is a low valley plain, but the southern side is a crescent-shaped steep bluff. The abruptness of this bluff contrasts strongly with the flowing contours of the neighboring country. It is possible that these

depressions were produced by the melting of large residual masses of glacial ice buried under the silt. I saw a similar bluff in looking over the country back of Cape Blossom.

There is nothing in the topography of the peninsula to suggest the direction of ice movement except that the ridges are prevailingly elongated easterly and westerly. These ridges, in so far as they are above sea-level, consist chiefly of silt, but, as we have seen, cores of boulder clay usually appear where they are bisected by the sea-cliff in a manner to indicate that the present topography is in large part controlled by the surface of the glacial deposit. The topography is not that typical of a terminal or lateral moraine but of a fluted ground moraine. All the till exposures examined corroborate the idea that it is ground moraine. Therefore, I incline to the opinion that these ridges are approximately parallel to the direction of ice movement like the major axis of a drumlin. Indeed, many of the shorter ridges approximate to the drumlin form, and if the silt covering were removed this form might be even more pronounced. Probably the ice that glaciated this country was a great glacier that came out of the broad valley of the Kobuk River on the east and extended into the Arctic Ocean. Mendenhall says:

> All of the peninsula which separates Hotham Inlet and Selawik Lake from Kotzebue Sound and its waters, with the exception of the extreme southwestern point (where members of the schistose series outcrop in Choris Peninsula), is made up of Pleistocene silts, clays, and embedded ice. Its outline and topography suggest that shoals which have formed off the mouths of the Noatak, the Kowak, the Selawik, and the Buckland have been raised into islands by slight local elevations, and that these islands have afterwards been tied into one long peninsula by the action of winds, waves, and currents.[1]

On the contrary, my investigation of that broad portion of the peninsula lying north of the latitude of Cape Blossom has led to the conclusion that it is a remnant of an undulating silt-covered drift plain into which the sea has cut on the western, northern, and eastern sides, producing a cliff from 30 to 100 feet high. The generally undissected character of the upland and the fresh appearance of the till suggest a late stage of glaciation presumably Wisconsin. This opinion is expressed with the fact in mind that erosion and weathering standards of the Temperate Zone are not applicable here

[1] U. S. Geological Survey *Professional Paper No. 10*, p. 45.

where the subsoil is permanently frozen to great depths. Partly coincident with the later stages of cliff cutting, and partly subsequent to the completion of certain portions of the cliff, has been the formation of a modern beach ridge. All parts of the latter are undoubtedly quite recent in age. The spit on which is situated the Friends' Mission consists of several strands, or separate beach ridges, between which are marshy depressions and freshwater lakes at levels from 5 to 10 feet above the level of the sea on one side and a brackish lagoon on the other side.

Presuming that the upland represents as late a stage as the Wisconsin epoch, the earlier stages of the sea-cliff erosion would occupy a larger part of the Recent period, the oldest of the beach ridges would be relatively modern in age and the youngest, on which the mission stands and which is yet in process of formation, would belong to a very late portion of this last epoch, perhaps the last 500 years. The marshy ground immediately behind it would be of similar youth. The age of these beach ridges and marshes is chiefly of interest in connection with the remains of large animals which occur on them.

Extending for about five miles along the northern shore of Hotham Inlet, northeast of the Pipe Spit, there is a sea-cliff from 30 to 75 feet high, interrupted by a valley one-half a mile wide. Sailing within several hundred feet of the western half of the cliff, I noticed in many exposures a stony clay of blue-gray color, doubtlessly till, extending nearly to the top of the bank. On the beach were some boulders derived from the cliff, but this is a less bouldery deposit than the till of the peninsula. Also, the till appears to be in places associated with irregularly stratified beds of sand and gravel. Landing at the eastern end of the cliff, I examined it westward for over two miles. West of the valley above-mentioned, all exposures were of stiff blue-gray till abounding in smoothed and striated pebbles and some boulders which were chiefly of limestone and calcareous schist, a few of greenish altered diorite, quartzite, gneiss, and vein quartz. There is a noticeable absence of the gabbroic rocks so prominent in the drift of the peninsula. The till extends nearly or quite to the summit of the cliff and the silt formation of the peninsula was not identified here.

The portion of the cliff east of the valley, extending about one and

one-fourth miles, is made up of irregularly interbanded till and modified drift. The latter is an indistinctly stratified sand and fine gravel containing many pebbles which yet preserve traces of faceting and striation. The till is a blue-gray sandy clay containing many striated stones and a few boulders, generally of limestone. The smaller rock fragments are mostly schist, limestone, and vein quartz, a drift notably differing in composition from that of the peninsula. Any exposed section of the cliff shows one or several bands of till 5 to 15 feet thick, occurring in places at the base or top, but generally about two-thirds of the distance from the bottom. Where at the top, it forms small stony knolls in the rolling upland back of the cliff. A portion of the cliff is protected from present erosion by a raised beach whose seaward margin is a steep bank rising 10 to 15 feet above the present beach.

About ten miles farther north there is a mountain range several thousand feet high. The gently undulating plain which, near the sea-cliff, is beyond doubt a glacial plain, extends inland to the foot of this range and a smooth slope extends thence to about midway of the height of the range where it appears, in a distant view, to terminate abruptly along a line which gently rises and falls, suggesting the upper limit of glaciation. Some low ranges of hills that would be included in the glaciated area have rather smooth topography but no features which of themselves would suggest glaciation.

On the northern border of the Kobuk Delta there are in places low bluffs produced by the most northerly channel of the river swinging into a gently undulating upland. Some of this upland country occurs southwest of the mouth of this channel and is bordered by a sea-cliff on the Hotham Inlet side. I did not land at any of these bluffs and cliffs but, seen from a boat, they appear to consist of a thick bed of brown and gray sandy silt like that over the till in the peninsula, but varying to portions much more largely of sand. The rolling plain topography characterizes the lower Kobuk Valley above the delta and the country between the delta and the mountains to the north. Indeed, as far east as I have been, namely, to the Shungnak River, outside of the modern alluvial plain in which the river winds about, the valley floor is everywhere an undulating plain rising from 30 to 200 feet above the river. In the lower valley this plain appears to

consist chiefly of silt, but farther east the ridges seem to be generally of coarser material, either modified drift (water-deposited sand and gravel) or of till. I did not often land at exposures of the latter, but the appearance of bluff faces at many places suggests it. I have no doubt that a careful study of this valley would bring to light moraines both terminal and lateral, but the rolling ground moraine seems to be the predominant feature of this drift.

The first decisive evidence of glaciation seen in ascending the Kobuk River is in a 150-foot bluff on the north side of the river below Squirrel River. As seen from a boat, the bluff appears to consist largely of a blue-gray stony clay, at one place resting on bed-rock. I landed at the Eskimo village at the mouth of Squirrel River and found blue-gray till exposed in the bluff. It abounds in striated stones, including a beautifully glaciated 6-foot boulder. The bank also contains much sand, probably modified drift. The north bank of the river, at a point at which I landed probably about midway between the Hunt and Ambler rivers, consists of a very stony till abounding in scratched pebbles. The country back of it has a morainic topography.

In the "Sketch Map of Alaska Showing Glacial Geology" in "The Geography and Geology of Alaska," etc., by Brooks,[1] published in 1906, the glaciated territory of the Endicott Mountain area is represented as terminating westward at about the mouth of the Ambler River, 173 miles above the mouth of the Kobuk River, and about 130 miles in a direct line from the drift near the mission on the peninsula. This is obviously an error. I traveled in the mountains near the Shungnak River, well within the reputed limit of glaciation, and while I recognized evidences of glaciation there, these evidences were not as pronounced in character as much that I saw in the lower Kobuk and Hotham Inlet regions. Similarly, on Seward Peninsula, I found in 1906 evidences of a more extensive glaciation than had been mapped by the U. S. Geological Survey in its preliminary work. I do not think that there was a general glaciation of northwestern Alaska, but that many of the valleys were occupied by glaciers that ran farther than has been indicated on the map mentioned above.

The Kobuk glacier probably occupied the entire Kobuk Valley. It may have been 230 miles long and 15 to 30 miles wide. It was

[1] U. S. Geological Survey Publications, *Professional Paper, No. 45*, Pl. XXII.

probably fed chiefly from the tributary glaciers on the southern slope of the Endicott range. The limestone, schist, and vein quartz drift on the north shore of Hotham Inlet was probably dragged from the hills on the north side of the Kobuk Valley (which are known to be made up largely of such rocks); the gabbroic drift of the peninsula probably was secured in the Hotham Peak range lying south of the Kobuk Valley. If there has been no important change in the relation between land and sea, the Kobuk glacier entered the Arctic Ocean.

BERKELEY, CAL.
April 17, 1908

# *Reviews*

*The Ann Arbor (Michigan) Folio.* By Frank Leverett. 15 folio pages of text and 3 maps. U. S. Geol. Surv., 1908. *Geologische Streifzüge in Heidelbergs Umgebung.* Von Dr. Julius Ruska. Eine Einführung in die Hauptfragen der Geologie auf Grund der Bildungsgeschichte des oberrheinischen Gebirgssystems. Pp. xi and 208 with numerous original views, maps, and sections. Nägele, Leipzig, 1908.

How often has the university professor felt the need of a convenient printed discussion of essentially local geological problems to which he can refer the student—something not too brief or so diluted as to distort the facts, but an adequate and readable presentation which the earnest student may turn to as a guide. In America this want has in a few instances been met by the geological folio of the university district, and whatever may be said of this form of publication with its endless duplications as applied wholesale throughout the country, it cannot be denied that as an aid to geological instruction at universities through description of the local geology it meets a real need.

The Ann Arbor folio and the German booklet referred to above are alike successful efforts in the direction indicated; the one for a great American university, the other for the oldest German university and the one which many American geologists claim as a second *alma mater*.

The American publication has the luxurious dress of its class, but suffers from its ungainly proportions, particularly when it is carried into the field. Its mechanical construction, while an aid to ready reference, detracts somewhat from the interest of perusal. Fortunately in this instance a most serious objection to the folio system—the patchwork truncation of the area by the accidents of quadrangle limits—is not serious, since Ann Arbor falls almost exactly in the center of the sheet.

The geological interest in the area is very largely restricted to the glacial and post-glacial history, and the significant distribution of the drift deposits with their modification in lake shores, has here been treated by one of our best authorities in that field. The whole subject of post-Wisconsin lake history, as applied to the Michigan area, is here for the first time comprehensively treated in an easily accessible publication. Excellent original

maps serve to set forth in sequence the many stages in this history, including that of the newly discovered Lake Arkona.

The book by Professor Ruska of Heidelberg is an initial attempt to meet a like demand at the German university. Dr. Ruska has the gift of literary style and the ability to present his subject in attractive form without loss of scientific accuracy. Different geological formations and significant surface features come each in turn under discussion in connection with well-planned excursions from Heidelberg. No less than 138 illustrations, many of them original and all well chosen, make the eye the pathway to the mind. Professor Ruska not only knows his field, but he has shown excellent judgment in selecting and arranging his material. W. H. H.

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*Rocks and Rock Minerals.* By LOUIS V. PIRSSON, Professor of Physical Geology, Yale University. 12mo, pp. 414. New York: John Wiley & Sons, 1908.

The new petrology by Professor Pirsson is a volume whose merits are more fully appreciated when one considers the difficulties inherent in the subject, not the least of which is that of classification. If it be remembered that the early and simple classifications based on megascopic characters have gradually become more and more complicated as microscopical investigations progressed until at present they cannot be satisfactorily used without the microscope, it may be admitted that a simplified classification for field work and similar uses has become extremely desirable. The classification adopted in the new work is essentially the same as the "field classification" first proposed in connection with the Quantitative Classification of Igneous Rocks, of Cross, Iddings, Pirsson, and Washington in 1903. On this basis Pirsson has succeeded in presenting in attractive style not merely the major facts of petrology, but also an excellent description of those things which give the science life and human interest. Thus, he not only defines a given rock from every point of view, but he describes its mode of occurrence, its alteration products, its various uses, and, frequently, its relation to ore deposits.

The book is, of course, not adapted to the needs of the geologist and petrographer, but to those of engineering and general students whose knowledge of the subject need not be profound. It is arranged in three parts: an introductory part of twenty pages dealing with the scope, history, and methods of petrology, and the chemical character of the earth's crust: a second part of 112 pages describing briefly the rock-forming minerals and giving short tables for their determination; and the main part dealing with igneous, sedimentary, and metamorphic rocks successively, and closing

with a short table for determining rocks. The illustrations are numerous and remarkably well chosen.

In discussing the origin of the porphyritic texture in igneous rocks Pirsson expresses the current view among petrographers in declaring that the idea of a change in the rate of solidification (for example, intratelluric and extratelluric crystallization) is not an adequate explanation of all occurrences. But it seems to the writer that the labile and metastable states proposed by Miers and indorsed by Pirsson as an explanation of the porphyritic texture are equally unsatisfactory. It seems to merely give names to certain conditions or states in magmas which may produce the texture, without explaining anything. Why such conditions should exist in some cases and not in others—in fact, why they should exist at all—is not clear. The writer would suggest that if we admit the existence of eutectics in igneous rocks (and Pirsson appeals to them to explain salic border zones) we have in their laws a reasonable explanation of the porphyritic texture. Thus, it is well known that any constituent present in a solution in greater amount than the eutectic proportion will begin to crystallize at a temperature above that required for the solidification of the eutectic itself, and will continue to crystallize until the cooling reaches that temperature; then the eutectic will crystallize at that temperature. It is clear then that with a uniform rate of cooling this process will give a much longer period of crystallization to the minerals in excess of the eutectic proportion than to the eutectic itself. This longer period of crystallization would naturally result commonly in larger crystals, that is, the porphyritic texture. In this connection it might be mentioned that Pirsson's statement on p. 171 that "the substance in greatest excess, the solvent, will solidify first" is quite misleading, since the substance in greatest excess is not necessarily the solvent nor the first thing to solidify.

Other minor errors include the crediting of tests of Wisconsin granites (p. 209) to Bain instead of to Buckley, and the omission of silicon in the paragraph on the elements of geological importance (p. 19). On p. 135 Pirsson defines as "hade" and "trend" what are ordinarily called dip and strike. It is not clear that anything is gained by the change, and it must result in some confusion. On the other hand he draws the distinction (p. 158) sharply and well between textures and structures in rocks, and describes numerous examples of each. His discussions of the difficult subjects of metamorphism, differentiation, etc., are remarkably well adapted in their simplicity and clearness to the place they occupy. As is to be expected, they reflect chiefly the views of the German school of petrographers.

A. N. W.

*The Fairbanks and Rampart Quadrangles, Yukon-Tanana Region, Alaska.* By L. M. Prindle Bulletin 337, U. S. Geological Survey.

*Geology and Mineral Resources of the Controller Bay Region, Alaska.* By G. C. Martin. Bulletin 335, U. S Geological Survey.

*Mineral Resources of Alaska*, 1907. By A. H Brooks and others, Bulletin 345, U. S. Geological Survey.

Following the policy of the Alaska Division of the United States Geological Survey of getting the results of its investigations before the public as soon as possible, the first bulletin is a concise summary of the present knowledge of the geology of the area covered by the topographic maps and issued at the time of their completion. Papers by G. C. Covert on the water resources of the Fairbanks region and the Rampart gold placer region by F. L. Hess are also included.

The second bulletin, on the other hand, is a detailed study of the coal-bearing rocks occurring in the area about Controller Bay and is a final report as far as is possible with the slight amount of development that has been done in the area. The age of the rocks is determined to be Miocene, with a possibility of the base of the series extending down into Oligocene. The rocks have been greatly disturbed and exact correlation made difficult by the lack of good exposures together with the present hazy state of our knowledge of the Tertiary of the Pacific Coast. Several terraces and benches indicate extensive recent elevation.

In the last bulletin is found the administrative report by A. H. Brooks, chief of the Alaska Division, together with several short papers by various members of the division summarizing present knowledge as to the occurrence and development of deposits of gold, copper, tin, coal, building-stone, and marble, together with papers on the methods of prospecting and mining, and the water supplies of the principal camps.

J. C. J.

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*The Iron Ores of the Iron Spring District, Southern Utah* By C. K. Leith and E. C. Harder Bulletin 338, U. S. Geological Survey.

This bulletin describes a small area in the southwestern corner of Utah, about 250 miles south of Salt Lake City. Sedimentary rocks of Carboniferous, Cretaceous, and Tertiary age have been intruded by large masses of andesite that are possibly laccoliths, and, after erosion, subsequent lava-

flows have covered the region. Later erosion has partly uncovered the older sediments and intrusives.

The ores are principally magnetite and hematite with a small amount of limonite, and occur (*a*) as fissure veins in the andesite, (*b*) as fissure veins and replacement deposits along the contact of the andesite and limestone, and (*c*) as a cement in a Cretaceous quartzite-breccia.

J. C. J.

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*Geology of the Rangeley Oil District, Colorado.* By Hoyt S. Gale. Bulletin 350, U. S. Geological Survey.

A small field at the western border of Colorado is described where considerable prospecting for oil has been going on with some success. The rocks are principally Cretaceous and Tertiary. The base of the Wasatch formation (Tertiary) rests with apparent conformity upon the top of the Mesaverde formation (Cretaceous), but the absence of formations found between them elsewhere in Colorado indicates a non-conformity here. The structure is a quaquaversal fold with little evidence of faulting. The oil occurs presumably in lenses in the Mancos (Cretaceous) shale.

J. C. J.